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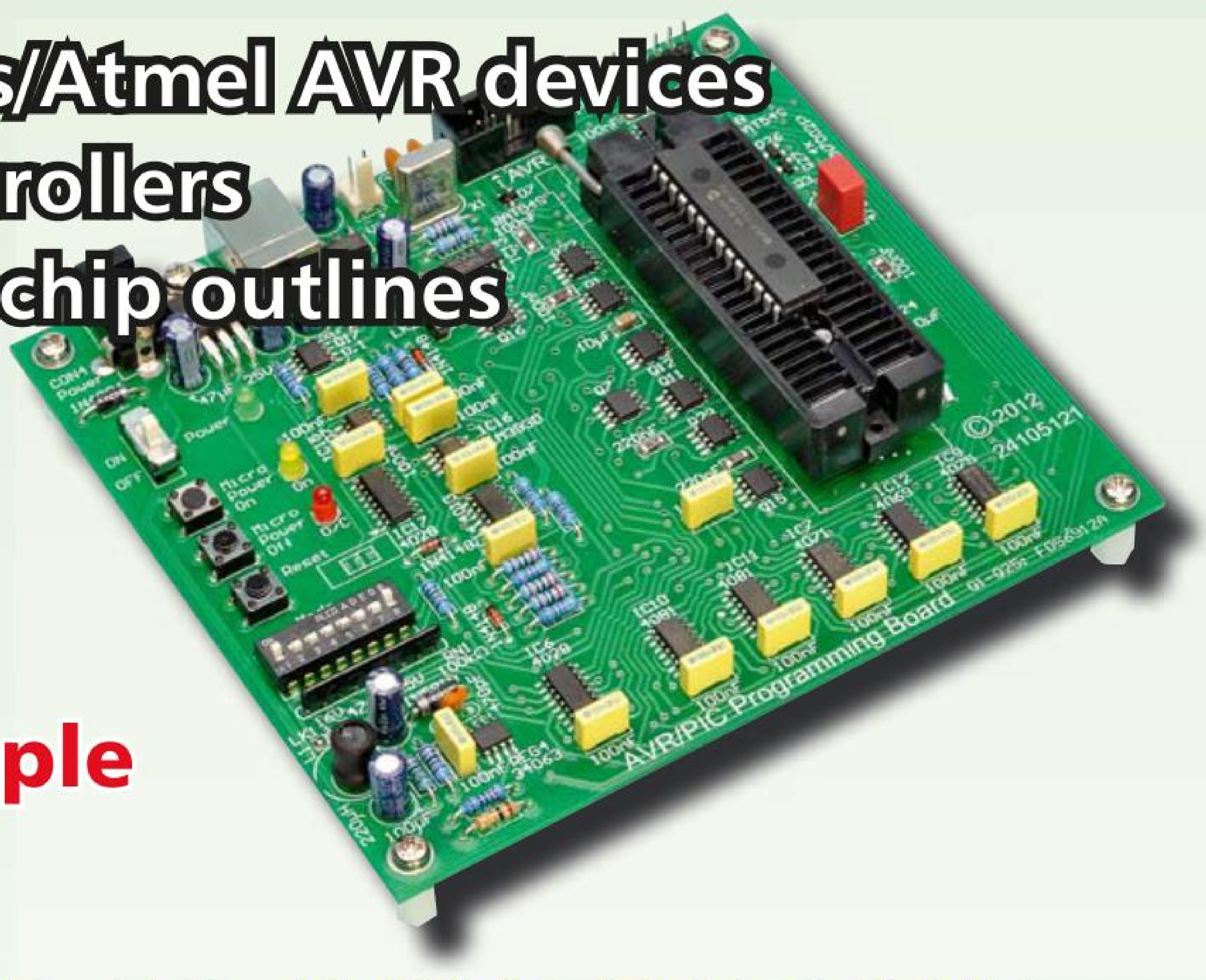

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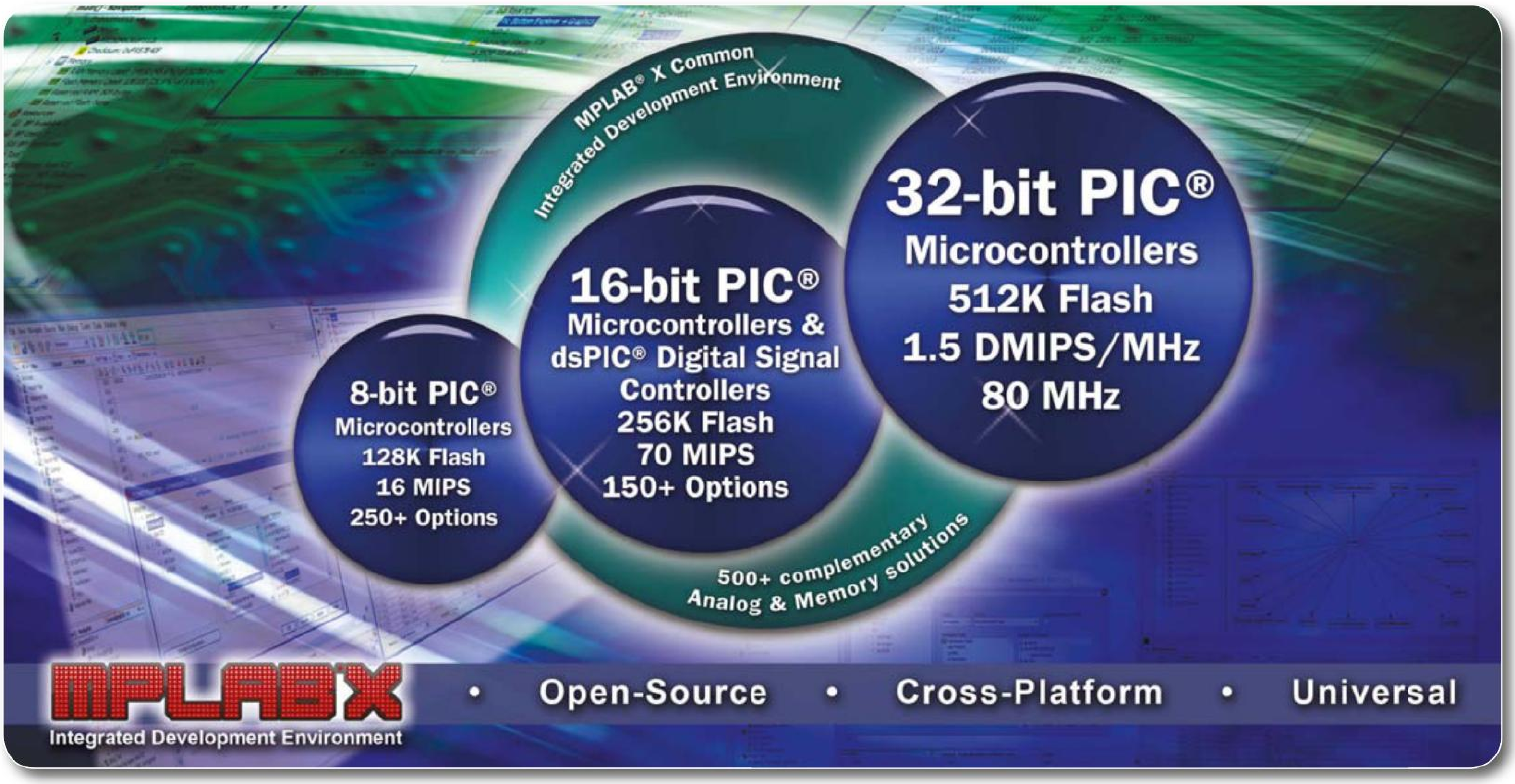
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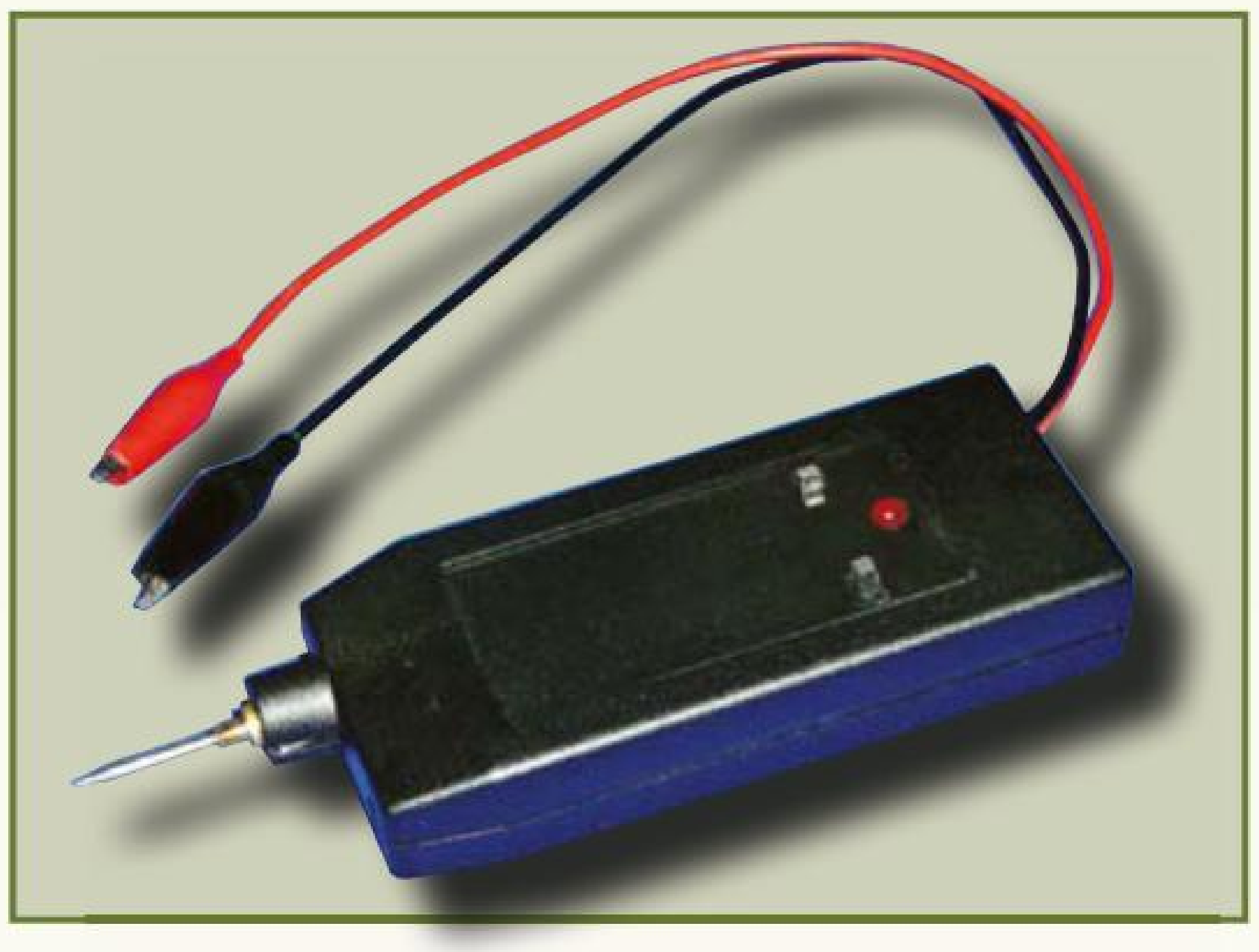

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Our June 2013 issue will be published on Thursday 2 May 2013, see page 72 for details.

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Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

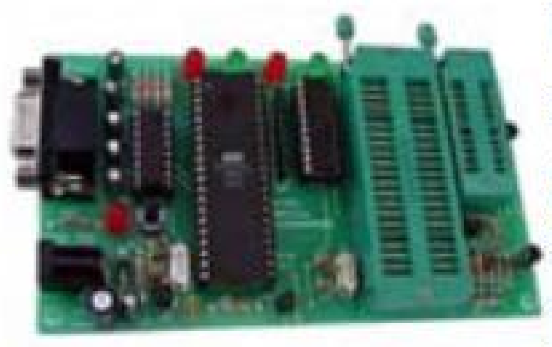
USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£64.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash PIC Programmer

USB PIC programmer for a wide range of Flash devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Powered via USB port - no external power supply required.
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer



Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£34.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£34.95**
Assembled Order Code: VM111 - **£44.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU446 £8.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055NKT - **£29.95**
Assembled Order Code: VM110N - **£43.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Mobile Phone NOT included

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£11.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 8191KT - **£29.95**
Assembled Order Code: AS8191 - **£39.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Stand-alone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£29.95**
Assembled Order Code: VM106 - **£44.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

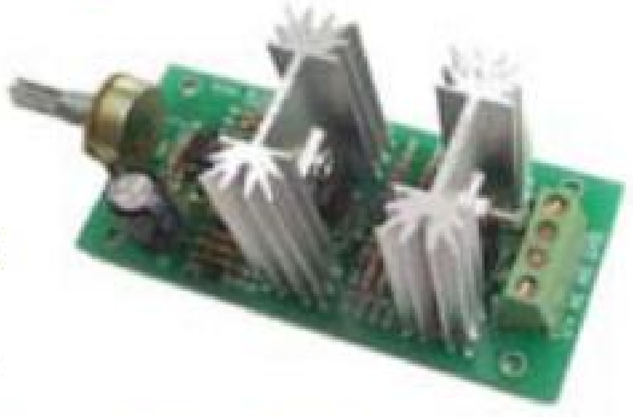
Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Bidirectional DC Motor Speed Controller

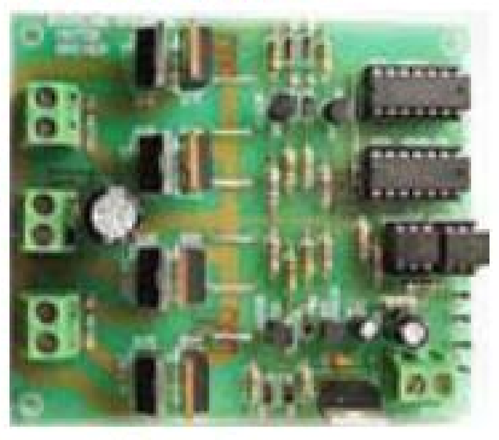


Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£17.95**
Assembled Order Code: AS3179 - **£24.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more DC, AC and Stepper motor drivers

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Order Code EPL500 - **£179.95**
Also available: 30-in-1 **£17.95**, 50-in-1 **£29.95,** 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£79.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~**£499.95**~~ **£394.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~**£189.95**~~ **£139.95**

See website for more super deals!

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Featured Kits in

Everyday Practical Electronics **May 2013**

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Don't Just Sit There...Build Something!

Simple 1.5A Switching Regulator Kit

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components.

- PCB: 49.5 x 34mm

Cat. KC-5508

Featured in EPE February 2013

£14.50*

USB Power Monitor Kit

Plug this kit inline with a USB device to display the current that is drawn at any given time. Check the total power draw from an unpowered hub and its attached devices or what impact a USB device has on your laptop battery life. Displays current, voltage or power, is auto-ranging and will read as low as a few microamps and up to over an amp. Kit supplied with double sided, soldermasked and screen-printed PCB with SMD components presoldered, LCD screen, and components.

- PCB: 65 x 36mm

Cat. KC-5516

£21.75*

Laptop not included

High Energy Ignition Kit for Cars

Use this kit to replace a failed ignition module or to upgrade a mechanical ignition system when restoring a vehicle. Use with virtually any ignition system that uses a single coil with points, hall effect/lumenition, reluctor or optical sensors (Crane and Piranha) and ECU. Features include adjustable dwell time, output or follow input option, tachometer output, adjustable debounce period, dwell compensation for battery voltage and coil switch-off with no trigger signal.

- Kit supplied with silk-screened PCB, diecast enclosure (111 x 60 x 30mm), pre-programmed PIC and PCB mount components for four trigger/pickup options

Cat. KC-5513

£18.25*

Mains Timer Kit for Fans and Lights

This simple circuit provides a turn-off delay for a 230VAC light or a fan, such as a bathroom fan set to run for a short period after the switch has been turned off. The circuit consumes no stand by power when load is off. Kit supplied with PCB, case and electronic components. Includes 100nF capacitor for 1 min to 20 mins. See website for a list of alternate capacitors for different time periods between 5 seconds to 1 hour.

- Handles loads up to 5A
- PCB: 60 x 76mm

Cat. KC-5512

£14.50*

Theremin Synthesiser Kit MkII

Create your own eerie science fiction sound effects by simply moving your hand near the antenna. Easy to set up and build. Complete kit contains PCB with overlay, pre-machined case and all specified components.

- PCB: 85 x 145mm

Cat. KC-5475

Featured in EPE March 2011

£27.25*

Universal Voltage Switch Kit

A universal module suits a range of different applications. It will trip a relay when a preset voltage is reached. Can be configured to trip with a rising or falling voltage making it suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more.

- Kit supplied with PCB, and electronic components.
- PCB size: 105 x 60mm

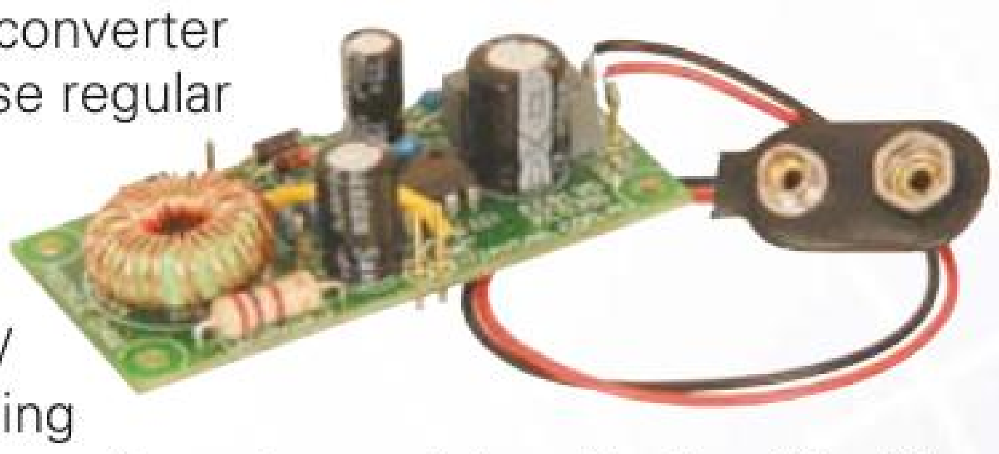
Cat. KC-5377

Featured in EPE December 2010

£12.00*

3V - 9V DC to DC Converter Kit

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell. Kit supplied with PCB, and all electronic components.



- PCB size: 59 x 29mm

Cat. KC-5391

Featured in EPE June 2007

£6.00*

SD Card Speech Recorder/Player Kit

Use this kit to store your WAV files on MMC/SD/SDHC cards. It can be used as a jukebox, a sound effects player or an expandable digital voice recorder. You can use it as a free-standing recorder or in conjunction with any Windows, MAC® or Linux PC.

- Short form kit includes overlay PCB, SD card socket and electronic components
- Compatible with SD, SDHC or MMC cards
- PCB: 164 x 136mm

Cat. KC-5481

Featured in EPE August 2011

£27.25*

Fast Ni-MH Battery Charger Kit

A truly versatile charger, capable of handling up to 15 of the same type of Ni-MH or Ni-Cd cells. Build it to suit any size cells or cell capacity and set your own fast or trickle charge rate. It also has overcharge protection including temperature sensing. Ideal for R/C enthusiasts who burn through a lot of batteries. Kit includes PCB and all specified electronic components. Case, heatsink and battery holder not included.

- PCB: 98 x 53mm

Cat. KC-5453

Featured in EPE August 2009

£11.00*

Luxeon Star LED Driver Kit

Luxeon high power LEDs are some of the brightest LEDs available in the world. They offer up to 120 lumens per unit, and will last up to 100,000 hours! This kit allows you to power the 1W, 3W, and 5W Luxeon Star LEDs from 12VDC. Use super-bright and energy efficient LEDs in your car, boat, or caravan.

- Kit supplied with PCB, and all electronic components.

Cat. KC-5389

Featured in EPE April 2007

£11.00*

Garbage and Recycling Reminder Kit

Easy to build kit that reminds you when to put which bin out by flashing the corresponding brightly coloured LED. Up to four bins can be individually set to weekly, fortnightly or alternate week or fortnight cycle. Kit supplied with silk-screened PCB, black enclosure (83 x 54 x 31mm), pre-programmed PIC, battery and PCB mount components.

- PCB: 75 x 47mm

Cat. KC-5518

£11.00*

SILICON CHIP
Jaycar
Garbage & Recycling Reminder

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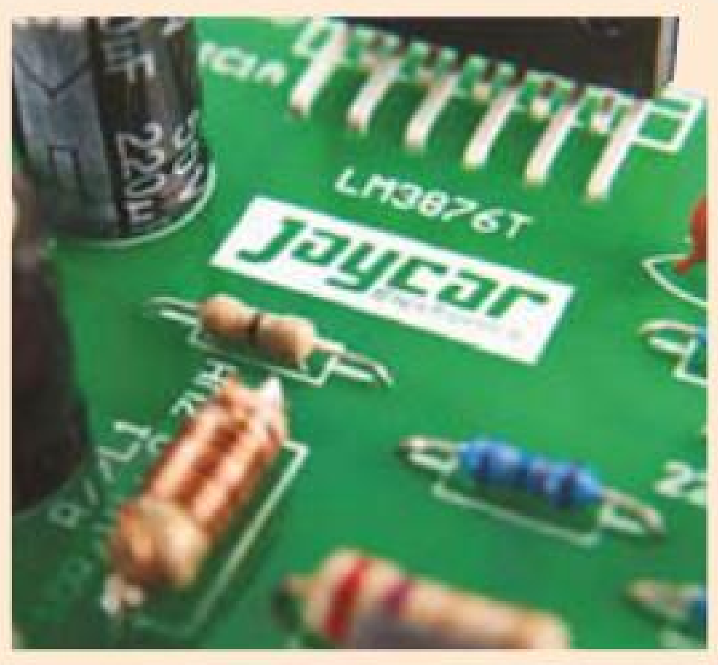
Our central warehouse keeps a quantity of older and slow-moving kits that can no longer be held in stores. A list of kits can be found on our website. Just go to jaycar.co.uk/kitbackcatalogue



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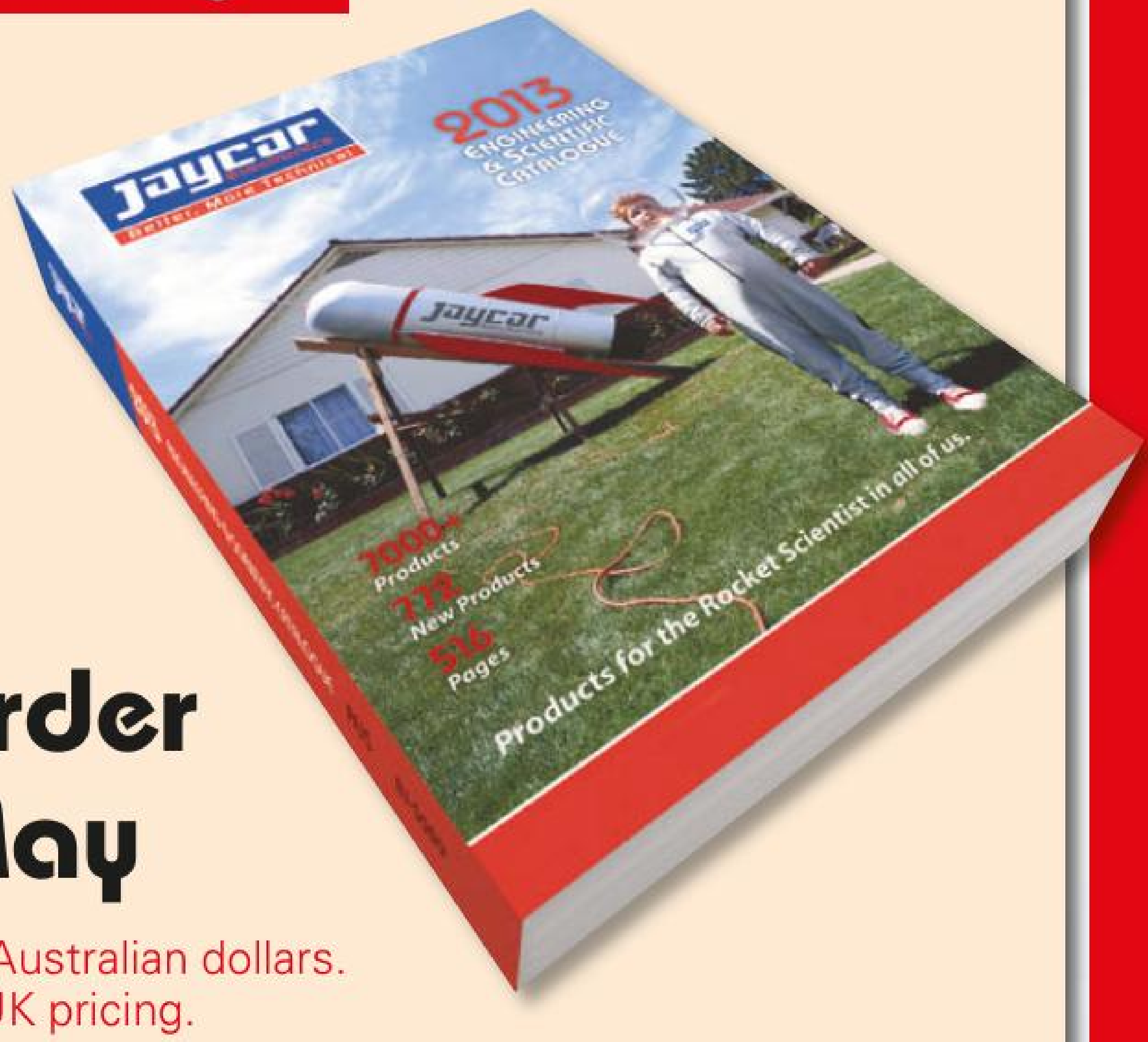
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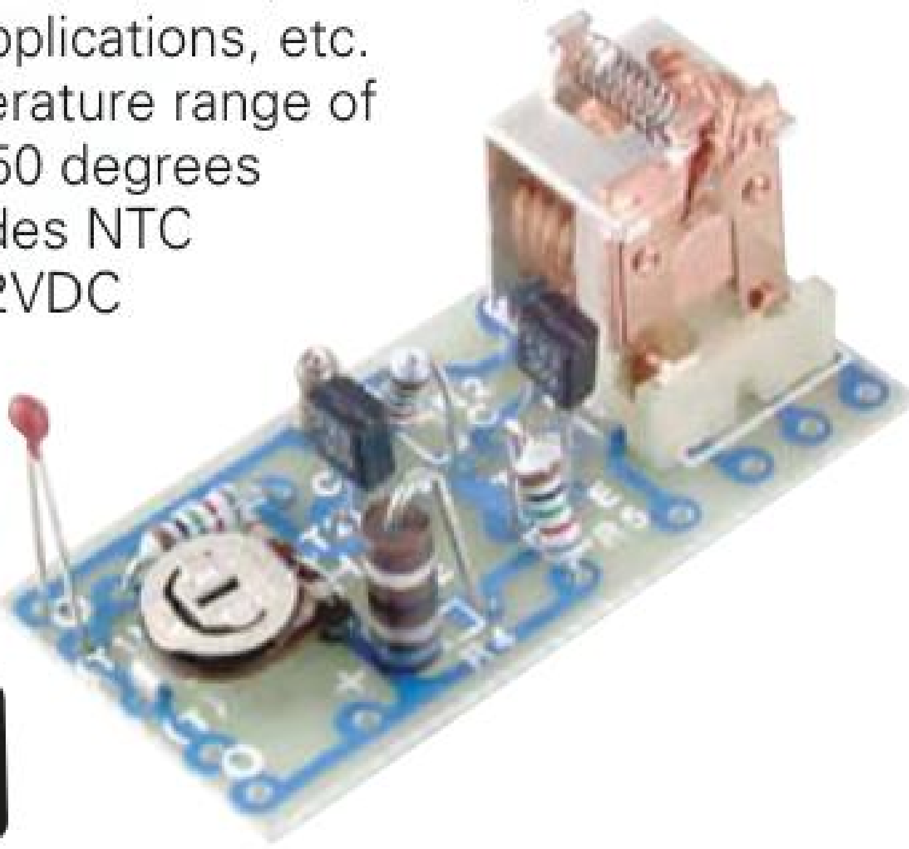

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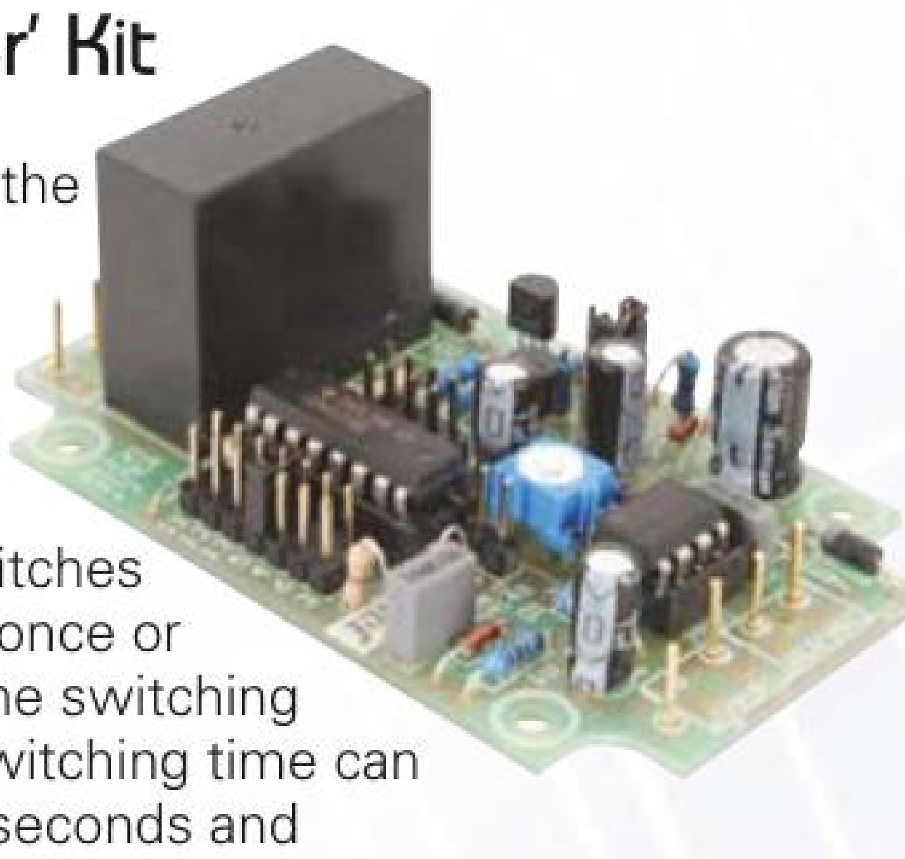

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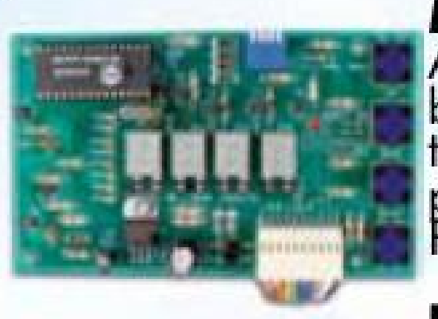

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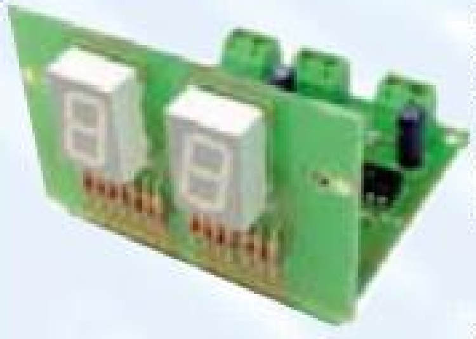

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MK127 Velleman kit £9.02

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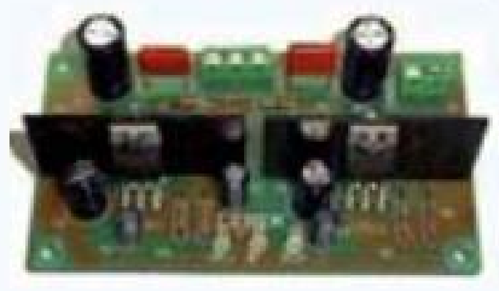

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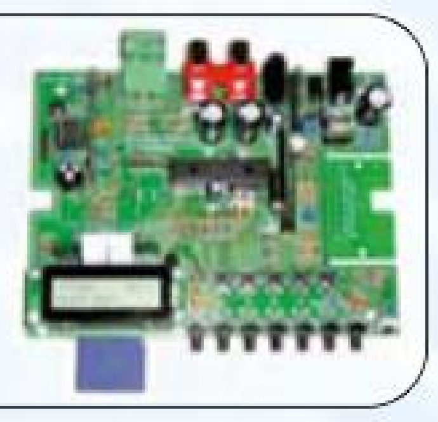

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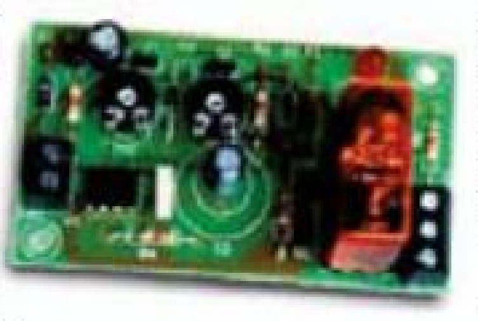

Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA

I-10 Cebek Module £14.12

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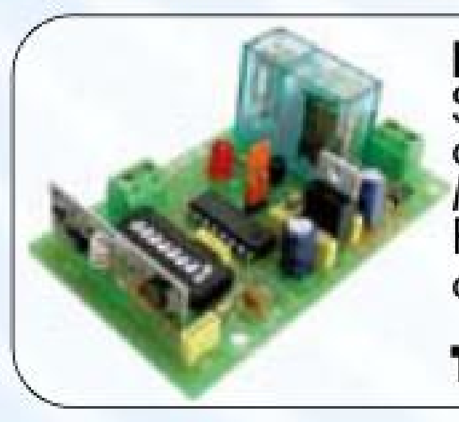

RF Remote Control Receiver
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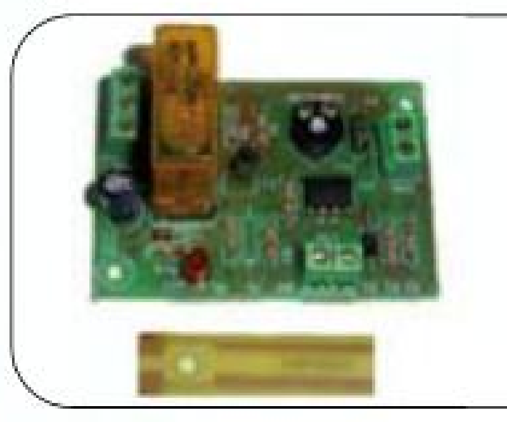
TL-1 Cebek Module £28.25



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Power: 12Vdc 60mA

I-6 Cebek Module £13.08

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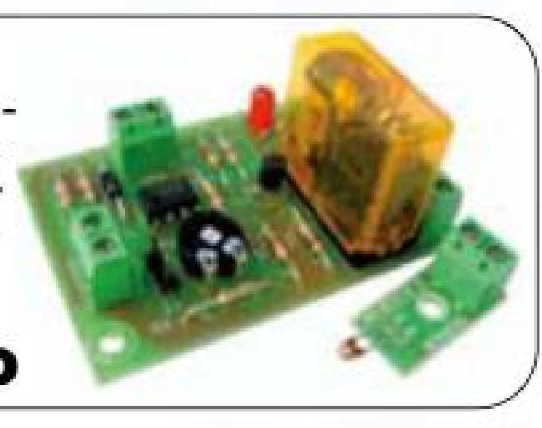

I-8 Cebek Module £12.80

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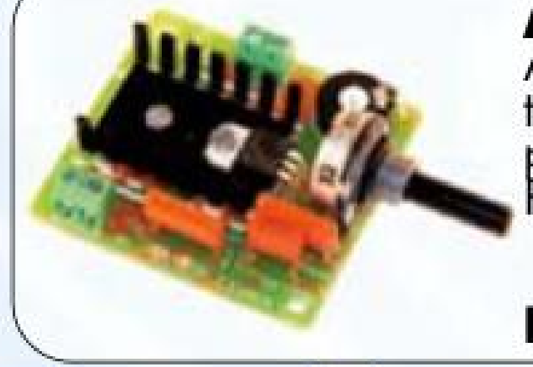
K8090 Velleman kit £39.95
VM8090 Module £58.40



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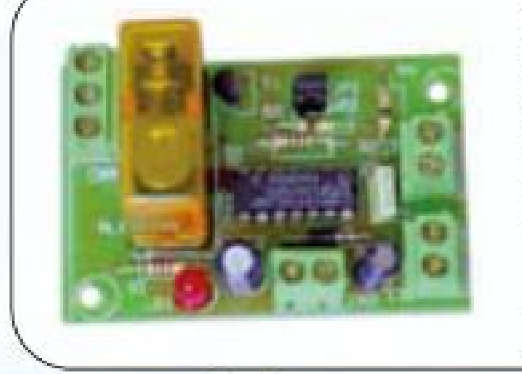
R-8 Cebek Module £12.14



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PICs, heartbeats and our website

Welcome to May's *EPE* – another issue stuffed from cover-to-cover with silicon-based inspiration!

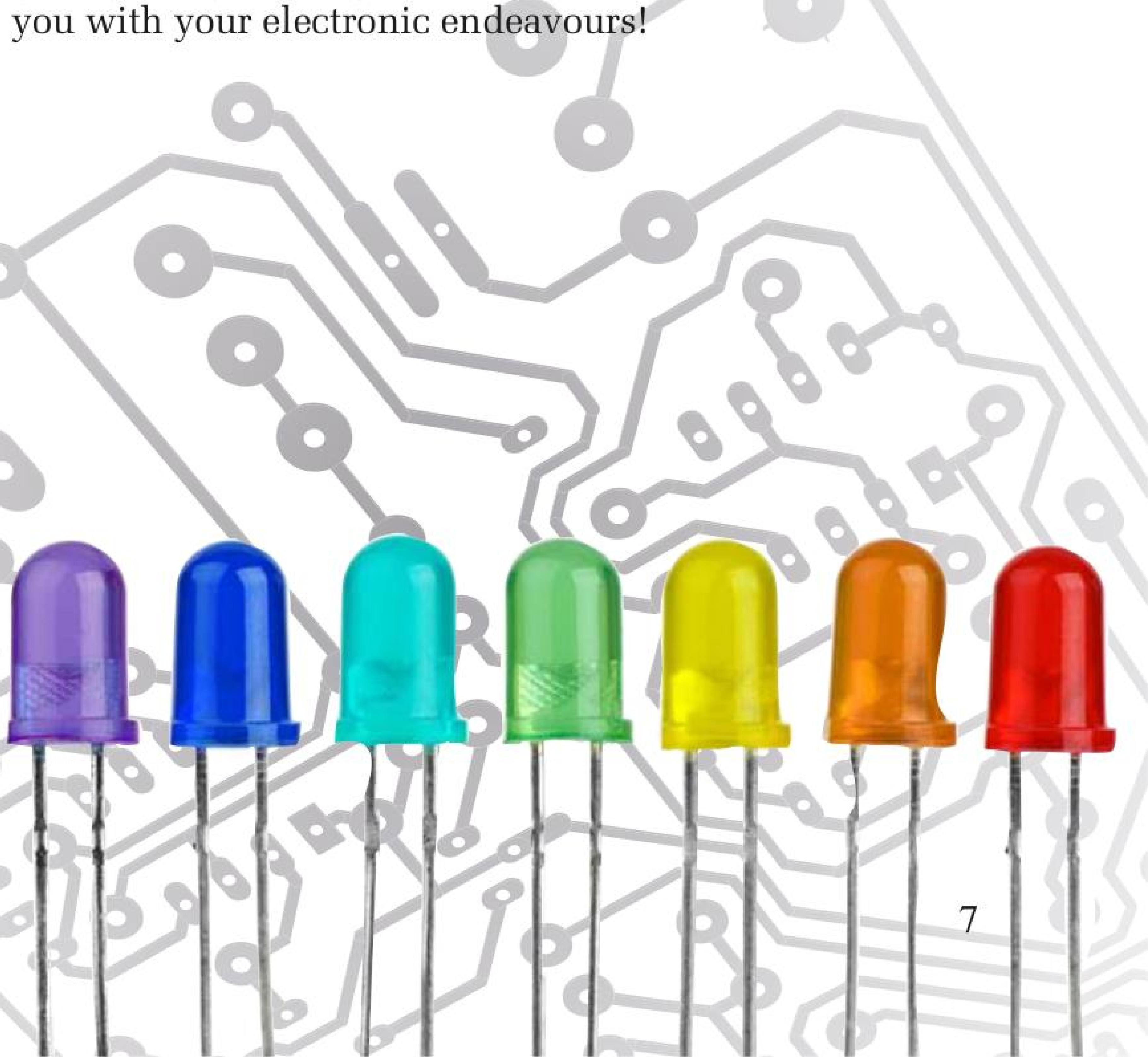
Two very different projects caught my eye this month. We know that many of you enjoy using PICs in our published projects, as well as your own, and the most frequently asked question from aspirant PIC users is: 'How can I program PICs?'. In fact, Charles Lekx, a Dutch reader who wrote in to this month's *Readout*, asks that very question. I would strongly encourage readers to review past issues for tips and guidance in Mike Hibbett's excellent *PIC 'n Mix* section.

However, for the more experienced among you we have a great project this month – the *PIC/AVR Programming Adaptor Board*. At the last count it could program over 450 Microchip and Atmel microcontrollers. It's a clever design with a great deal of in-built flexibility that makes programming as pain-free as possible.

From digital to analogue – the other project I particularly enjoyed editing for this issue was the all-analogue design of our *Electronic Stethoscope*. It's an elegant combination of amplifiers, filters and ingenious mechanical components that will have you listening to sounds that are simply undetectable with the unaided human ear. Heartbeats and engine rattles become clear, and you can even have fun listening to distant conversation using the 'directional hood'.

I'd like to remind readers that *EPE* has an extensive website, which has recently been given a substantial overhaul by our *On-line* editor, Alan Winstanley. It really is a big improvement that makes accessing all our online goodies much easier. At **www.epemag3.com** you can subscribe to the online version of *EPE*, access downloads for projects (program files, PCB designs and artwork for cabinets) as well as joining in the fun in *Chat Zone*, our indispensible online forum for all readers of *EPE*. Got an electronics problem? The chances are good someone will help you in *Chat Zone* – it's a very friendly forum with many experienced and helpful readers from the UK and around the globe.

Last, but not least, do please keep sending in your letters and *Ingenuity Unlimited* ideas. We greatly enjoy reading them and you may well win a 'grand prize' to help you with your electronic endeavours!



NEWS

A roundup of the latest Everyday News from the world of electronics

Philips works with Chinese giant – by Barry Fox

Getting hard-fact information from Japanese, Korean and Chinese companies is becoming increasingly difficult. The Chinese instinctively mistrust all journalists; employees of Korean companies live in fear of head office in Seoul; and Japanese companies worry about saying anything that could help their Chinese and Korean competitors.

Philips of the Netherlands has so far been a welcome exception, talking usefully about technology. So we wondered what would happen when, in April 2012, Philips did a 30/70 joint venture deal with Chinese TV and monitor giant TPV.

Dutch-Chinese partnership

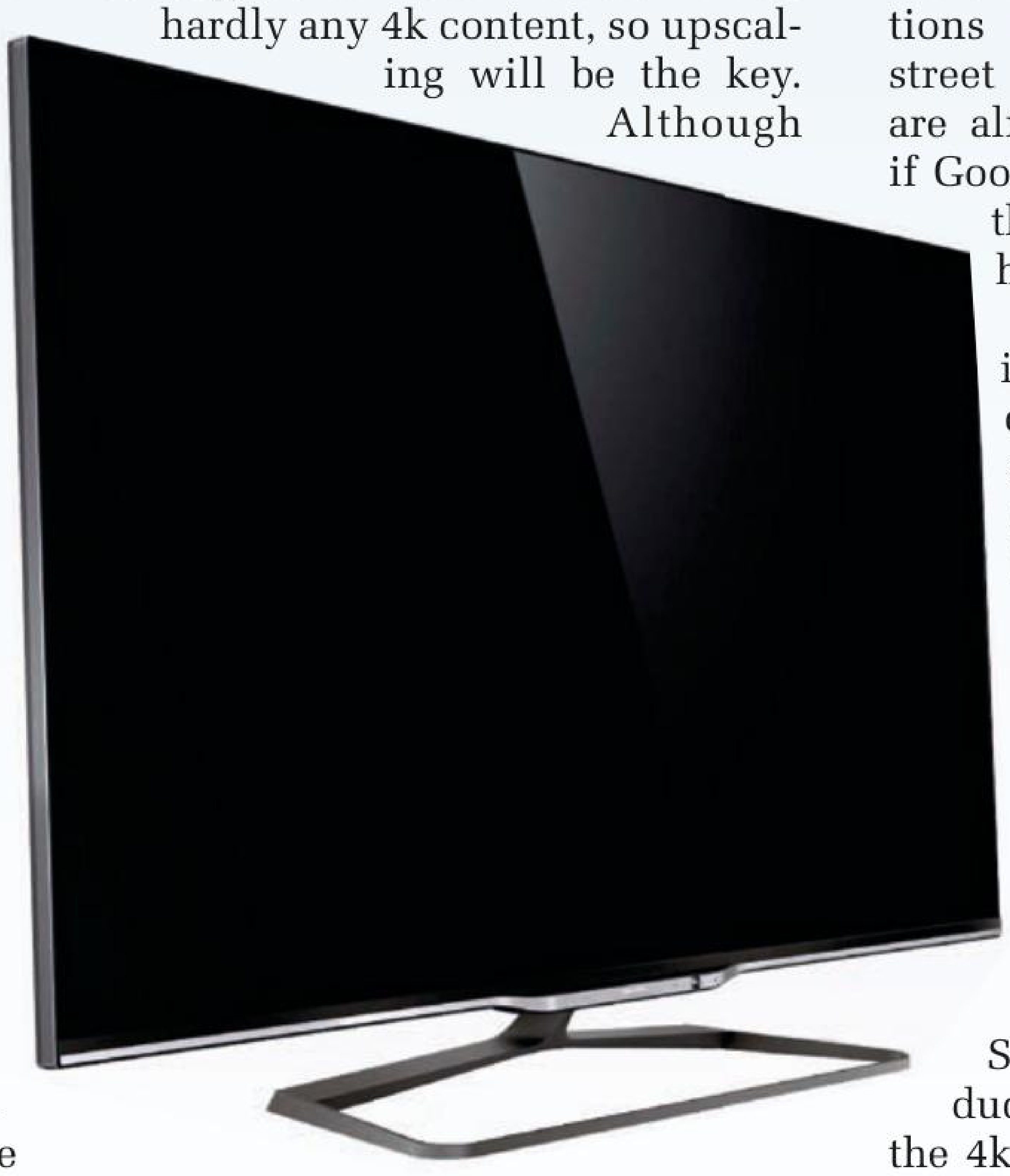
The joint venture is called *TP Vision*, and a recent flying visit to its new HQ in Amsterdam reassured that, for the time being at least, the Philips engineers who are designing the TV sets that the Chinese factory will make for sale under the Philips brand name, are still able to talk usefully.

Different countries will take different models to suit local market requirements, explained CEO Maarten de Vries, after unveiling a new range of around 50 TVs for Europe. The UK will take 35 models, including the top end 9000 series, which (in Bang and Olufsen style) combines a 55-inch or 46-inch Full HD 2k panel with a large sheet of reinforced glass, which then acts as a ground support.

Some TP Vision Smart TV sets have a built-in Skype camera, but this can be covered with a sliding door, manually operated. This option was added after news broke that hackers could gain remote access to the video stream. Surprisingly, there is no manual muting for the double microphone at the set front.

The *IFA Show Berlin* in September will be the 'launchpad window' for TP Vision's new 4k Ultra HD TV sets, with a proprietary upscaling 2k-to-4k system called Ultra Resolution.

'We see upscaling as the battleground for 4k' said Danny Tack, director of product planning and strategy at TP Vision. 'There will be hardly any 4k content, so upscaling will be the key. Although the broadcasters will put more effort into delivering 4k programmes than they did with 3D – because they accept they made a mistake with 3D – people will still only be able to get a few movie documentaries in 4k from the Internet or Japan. Ninety-nine percent of what people watch will be upscaled from Full HD to 4k. Different brands will differentiate on upscaling, which is why we see it as the 4k battleground. Ultra Resolution builds on the Philips heritage of Pixel Plus image enhancement.'



Philips-TVP 7008 series smart TV

Using a 4k 60-inch screen, Tack showed computer simulations of what his team of engineers, currently still based at Philips' research centre in Bruges, Belgium, has been working on. Still pictures and slowly moving video were screened first in Full HD and then upscaled to 4k.

The most impressive demonstrations were of Google maps and street maps, which, Tack noted, are already available in native 4k if Google's server detects a display that can match the required high resolution.

Processing speeds for upscaling will have to be double the current two billion pixels per second used for Full HD processing. Although the number of pixels to be processed increases fourfold, the first 4k panels will have a refresh rate of 100Hz, instead of the 200Hz used for top-range Full HD panels. So the processing doubles to four billion pixels per second.

HDMI version

Sony, Samsung and LG have all ducked my questions on whether the 4k TVs they are already selling can have their HDMI Ver. 1.4 connectors upgraded to Ver. 2.0 when the imminent new HDMI standard is set. TP Vision was far more upfront on this contentious issue.

TP Vision's 4k sets will also launch with HDMI Ver. 1.4 connectors, Danny Tack confirms. 'This limits 4k frame rate to 30Hz. Gaming and 3D will be limited to 30Hz, but both will benefit from 4k. HDMI Ver. 2.0, for 4k at 60Hz, will arrive too late for 2013.

'We don't know whether the Ver. 1.4 connectors will be upgradeable' he says, frankly admitting that because new high-speed silicon will

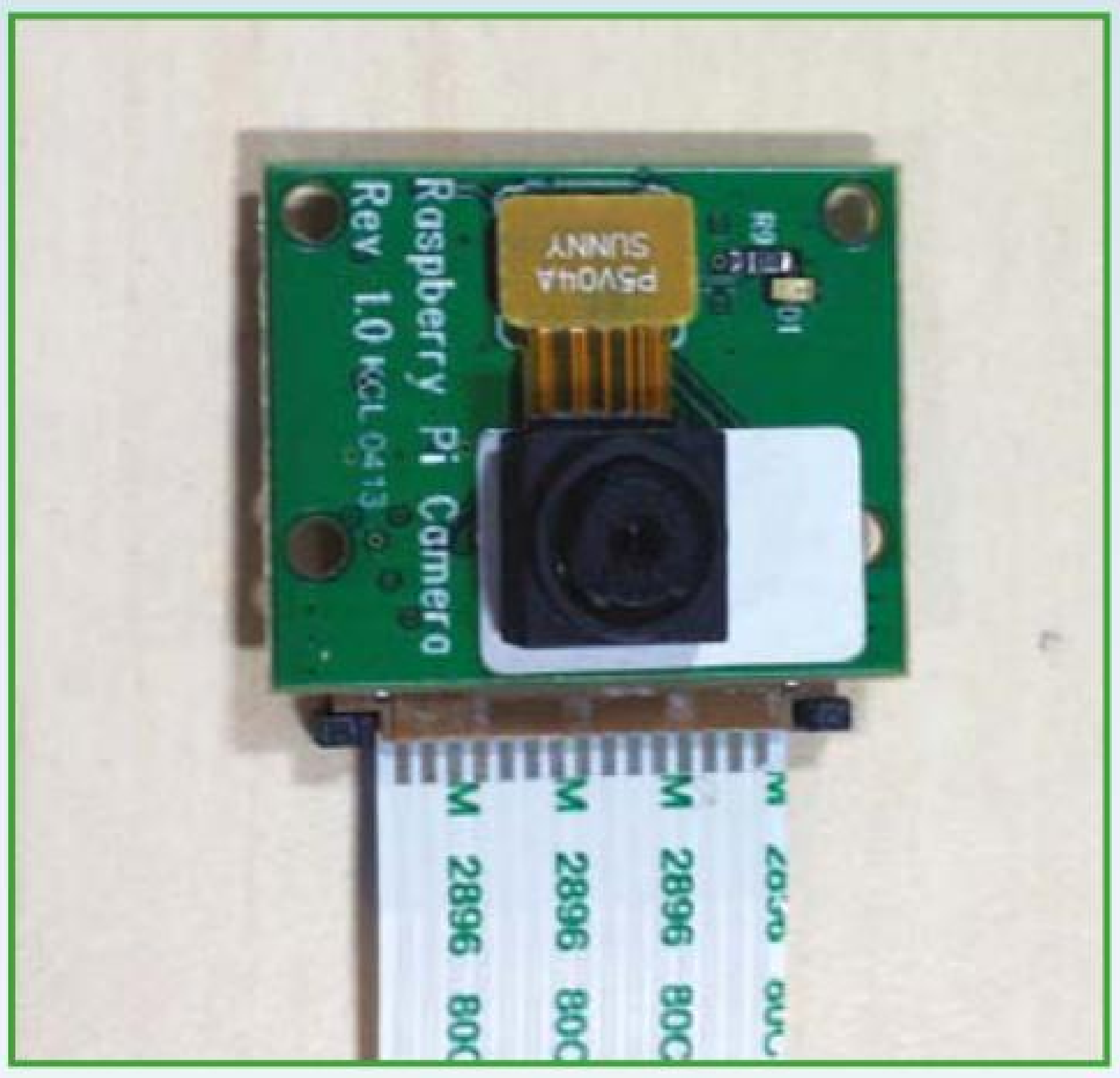
Philips works with Chinese giant – contd

be needed for Ver 2.0, it is unlikely that any device sold with HDMI Ver 1.4 connectors will be user-upgradeable to Ver. 2.0.

There are no 21:9 sets in the new TP Vision range. British MD Graham Speake and Danny Tack explained why the cinema wide format, previously pioneered by Philips, using custom panels sourced from Sharp and LG, was missing.

'It's stopped. There was no industry support. We led and no one followed. Never say never, but for the time being it's stopped. All the 21:9 sets Philips made have now been sold.'

Pi-cture perfect



A camera for the Raspberry Pi – priced at $25

The Raspberry Pi Foundation has revealed its first official add-on for its popular credit-card-sized, low-cost computer – the Raspberry Pi. The new device is a five megapixel camera.

The tiny electro-optical board measures just 20 × 25 × 10mm, and comes with a 150mm cable. It can capture pictures and 1080p HD video. The add-on is expected to appear on sale later this year, and will be priced at just $25.

The new camera will plug straight into the Pi's mainboard, so bandwidth won't be constrained by the USB interface.

As well as taking still pictures, it can record HD video at 15 to 60 frames-per-second. The camera's image sensor is made by Omnivision, and features include automatic control of exposure and white balance (colour temperature settings).

Liz Upton, the Foundation's marketing manager, says 'The camera module hardware has been finalised, but the board's software drivers need some work before the device can be released'.

Home security, aerial videography and robotics are just a few of the anticipated applications for the new Pi peripheral.

LEDs GONE IN A FLASH

The revolutionary new capacitor material is the flat black object below the aluminium xenon flash tube holder

A Singapore invention looks set to equip mobile phones with a built-in, small yet powerful xenon flash, allowing consumers to take great photos even in low-light conditions. Most mobile phones use bright white LEDs, but these have limited power and tend to give images a bluish caste.

Xenon flashes incorporate a glass tube filled with xenon gas, and emit a high-intensity burst of white light that's much brighter than LED flashes typically found on smartphones.

Prof Lee and researchers from Nanyang Technological University (NTU) have made a revolutionary capacitor that overcomes limitations in existing capacitors, which are needed to store enough energy to fire a powerful flash, like those found on digital cameras, but which have so far been too big to fit in slim mobile devices.

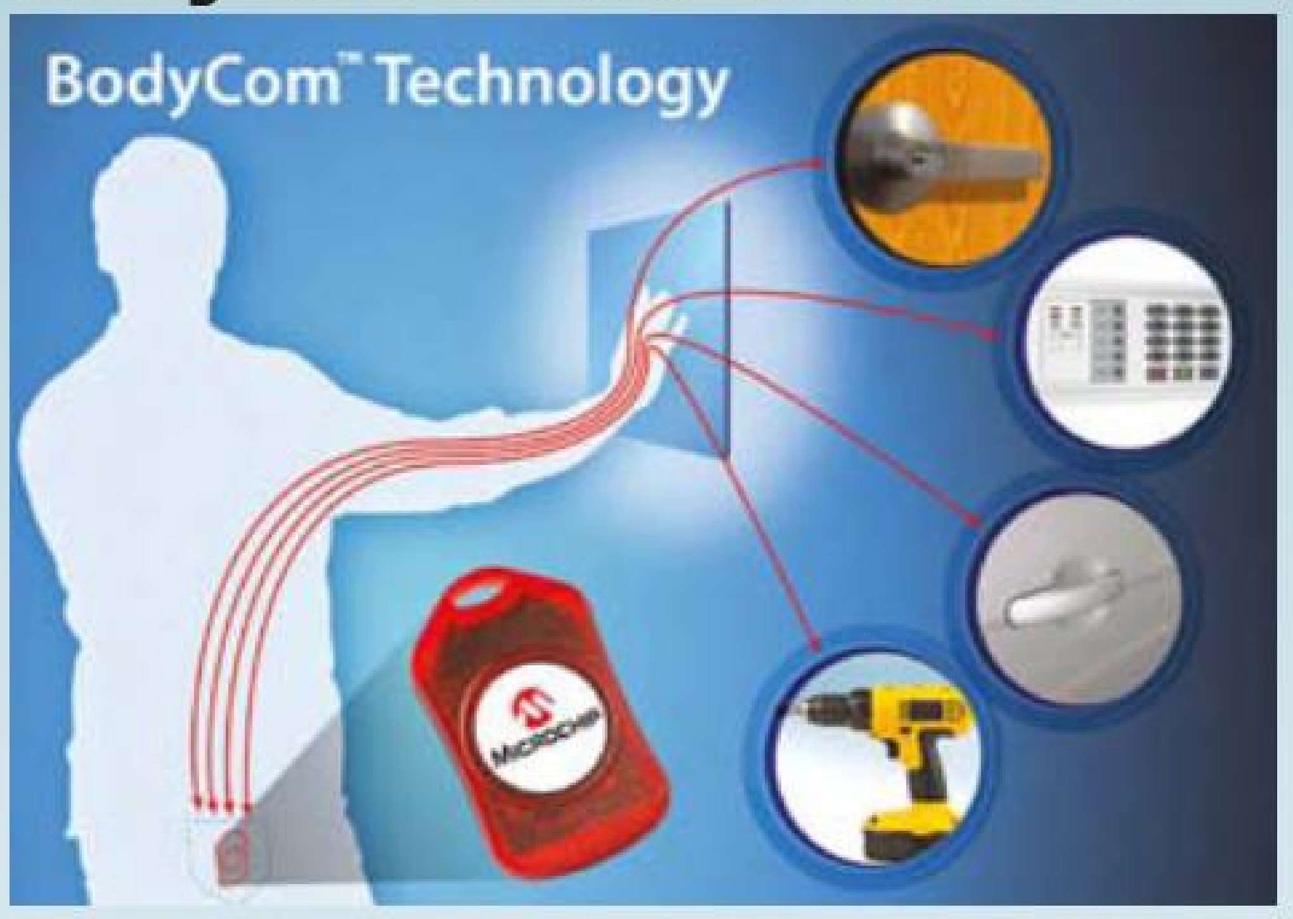
Made from polymer layers, the new capacitor is at least four times smaller than current electrolytic capacitors. Also, the charge and discharge times are faster than other types of energy storage devices, making it especially suitable for powering xenon flash applications.

Furthermore, capacitors made using this grafted co-polymer are flexible, making it easier to shape them to fit into the confined spaces of modern ultra-slim electronic products.

NTU, and their industrial partner Xenon Technologies, hope that a commercial prototype of a flash-capacitor combination will be available from September this year.

It's not all bad news for LEDs. While xenon flash is undoubtedly better for taking stills, for video work, xenon is useless – it is only a 'flash'. However, LEDs can stay on for as long as battery power is available, making them useful for low-light video shooting.

Microchip pioneers human body as comms channel



Short-range, low-power keyless security

Microchip, the PIC producer, has announced its BodyCom technology, which provides designers with the world's first framework for using the human body as a secure communication channel.

Compared to existing wireless methods, they claim BodyCom provides lower energy consumption, while further increasing security via bidirectional authentication. Because no RF antennas are required, BodyCom allows for simpler designs.

The technology is activated by capacitively coupling the human body. The system then begins communicating bidirectionally between a centralised controller and one or more wireless units.

There is a broad range of applications where secure wireless communication is essential, and there is no more secure channel than the human body. This is especially true when you add bidirectional authentication that supports advanced encryption. For more information, see Microchip's short video: **www.microchip.com/get/9TMM**

Stretchable batteries

Researchers at Northwestern University and the University of Illinois in the US have developed stretchable batteries that can be used to power a new generation of flexible electronics. The batteries, it's claimed, will allow stretchable electronic devices to be used anywhere, including inside the human body, where they could monitor anything from brain waves to heart activity, succeeding where flat, rigid batteries would fail.

The design works, even when stretched, folded and twisted. It can deliver power and voltage similar to a conventional lithium-ion battery of the same size, but can stretch up to three times its original size and still function.

The researchers start with an array of tiny batteries side by side in a very small space, and connect them with tightly packed, long wavy wires. When stretched, the wires unfurl, much like yarn unspooling.

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Electronic Stethoscope

By JOHN CLARKE

Need to do a bit of self-diagnosis? Make sure your heart is still beating or check other body sounds? Maybe you would like to sort out some unusual rattle or noise in your car's engine or another piece of machinery?

This electronic stethoscope will do the job – and you can listen via headphones or a loudspeaker. It has switchable frequency shaping in four bands, so you can hone in on sounds which might otherwise be masked out.

Features

- Portable
- Battery supply
- Volume control
- Boost or cut control
- Selectable tone frequency
- Reverse supply protection
- Power indicator
- Battery condition indicator

SO WHY have an electronic stethoscope when a traditional cheap and cheerful stethoscope might be all you need?

Well, a conventional stethoscope is OK if you have keen hearing and you are listening in a quiet environment, but its sound levels are modest, particularly at low frequencies.

Second, on a cheap stethoscope there is no way of tailoring the frequency response of sound heard at the earpiece (apart from choosing the diaphragm or bell on the chestpiece of a medical stethoscope).

This *Electronic Stethoscope* has plenty of gain – you can adjust the volume level to suit and you can use switchable filtering to cut or boost a particular band of frequencies. Also, it can be connected to headphones or a loudspeaker, in which case more than one person can hear the sounds.

If you wanted to, you could record the monitored sounds and display the waveforms on a computer screen.

Our *Electronic Stethoscope* comprises a chestpiece (sound pickup) that connects to a small amplifier box via a shielded cable. It has a headphone socket, knobs for volume and equaliser (EQ) potentiometers and switches for power and frequency band selection.

Frequency band

The equaliser provides boost or cut in the frequency band selected by the 4-position slide switch. These bands are centred on 63Hz, 250Hz, 1kHz and 4kHz and are labelled Low, Mid1, Mid2 and High respectively.

To simulate the bell sensor (of a medical stethoscope) where low frequency sounds are more prominent, the Mid2 band can be selected and the equaliser control set for an amount of signal cut. Or the low band could be selected with the equaliser control set in the boost position. To simulate the chestpiece diaphragm, the high band can be selected and the 'EQ' pot set to the cut position.

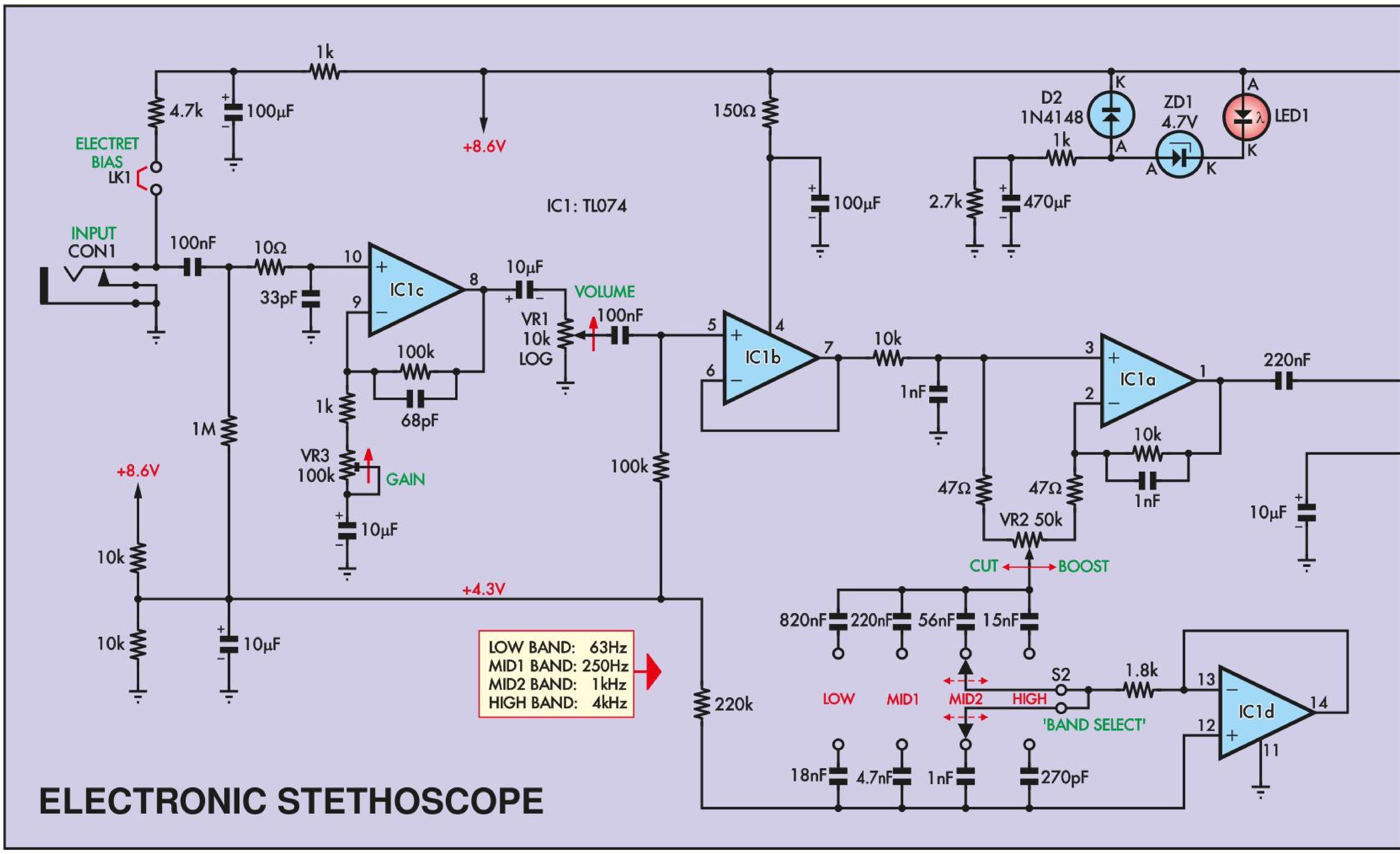

1k
4.7k
100µF
ELECTRET BIAS
LK1
+8.6V
150Ω
100µF
D2 1N4148
1k
2.7k
470µF
ZD1 4.7V
LED1
A
K
IC1: TL074
INPUT CON1
100nF
10Ω
33pF
10
9
8
IC1c
10µF
VOLUME
VR1 10k LOG
100nF
5
6
4
7
IC1b
10k
1nF
3
2
1
IC1a
220nF
10k
1nF
100k
68pF
1k
1M
VR3 100k
GAIN
10µF
+8.6V
10k
10k
10µF
100k
+4.3V
47Ω
47Ω
VR2 50k
CUT
BOOST
10µF
820nF
220nF
56nF
15nF
LOW BAND: 63Hz
MID1 BAND: 250Hz
MID2 BAND: 1kHz
HIGH BAND: 4kHz
220k
LOW
MID1
MID2
HIGH
S2
'BAND SELECT'
1.8k
13
12
14
11
IC1d
18nF
4.7nF
1nF
270pF
ELECTRONIC STETHOSCOPE

Fig. 1: the *Electronic Stethoscope* circuit is based on two low-cost ICs – an amplifier (IC1a), buffer (IC1b), frequency band selection (IC1c and IC1d) and finally, a power amplifier capable of driving a set of headphones or 'ear buds' (IC2). It's all powered by a 9V battery.

Alternatively, any one of the bands can be selected by the switch and the equaliser pot can be set to boost or cut. Boosting the frequency band selected will make more prominent any sounds of interest within that band. Conversely, the cut position will remove prominent sounds in a band that may otherwise mask out the sounds of interest.

The chestpiece is adapted from a low-cost stethoscope, but with a piezo transducer fitted inside. For use with car engines or other machinery, the chestpiece is further modified to provide a more direct contact with the piezo transducer element.

Circuit details

The *Electronic Stethoscope* is based on two low-cost ICs: a TL074 quad op amp (IC1) and an LM386 power amplifier (IC2). The op amps are used for amplification and filtering of the signal from the piezo element in the chestpiece. The power amplifier drives the headphones or a loudspeaker. The full circuit diagram is shown in Fig.1.

The piezo element signal is applied via CON1, a 3.5mm socket and a 100nF capacitor to op amp IC1c. The associated 33pF capacitor and 10Ω resistor attenuate high frequencies, reducing the possibility of picking up radio signals. IC1c is biased at +4.3V via the 1MΩ resistor connected to the 10kΩ voltage divider resistors across the 8.6V supply. The 1MΩ resistor also sets the amplifier's input impedance.

Note that bias for an optional electret microphone is included and is fed via link LK1 and a 4.7kΩ resistor to the 8.6V supply via a 1kΩ resistor and 100µF bypass capacitor. (Electret bias is included so that the stethoscope can be used in a different application. See the section entitled 'Using the stethoscope as an audio eavesdropper').

Op amp IC1c is connected as a non-inverting amplifier with a gain that can range from about two, when trimpot VR3 is set at 100kΩ, and up to 101 when VR3 is set to its minimum resistance. Its output is coupled to the Volume control potentiometer, VR1, via a 10µF capacitor.

The output of VR1 (wiper) is fed to IC1b, which is connected as a unity-gain buffer. The output from IC1b drives the equaliser (EQ) stage consisting of op amps IC1a and IC1d.

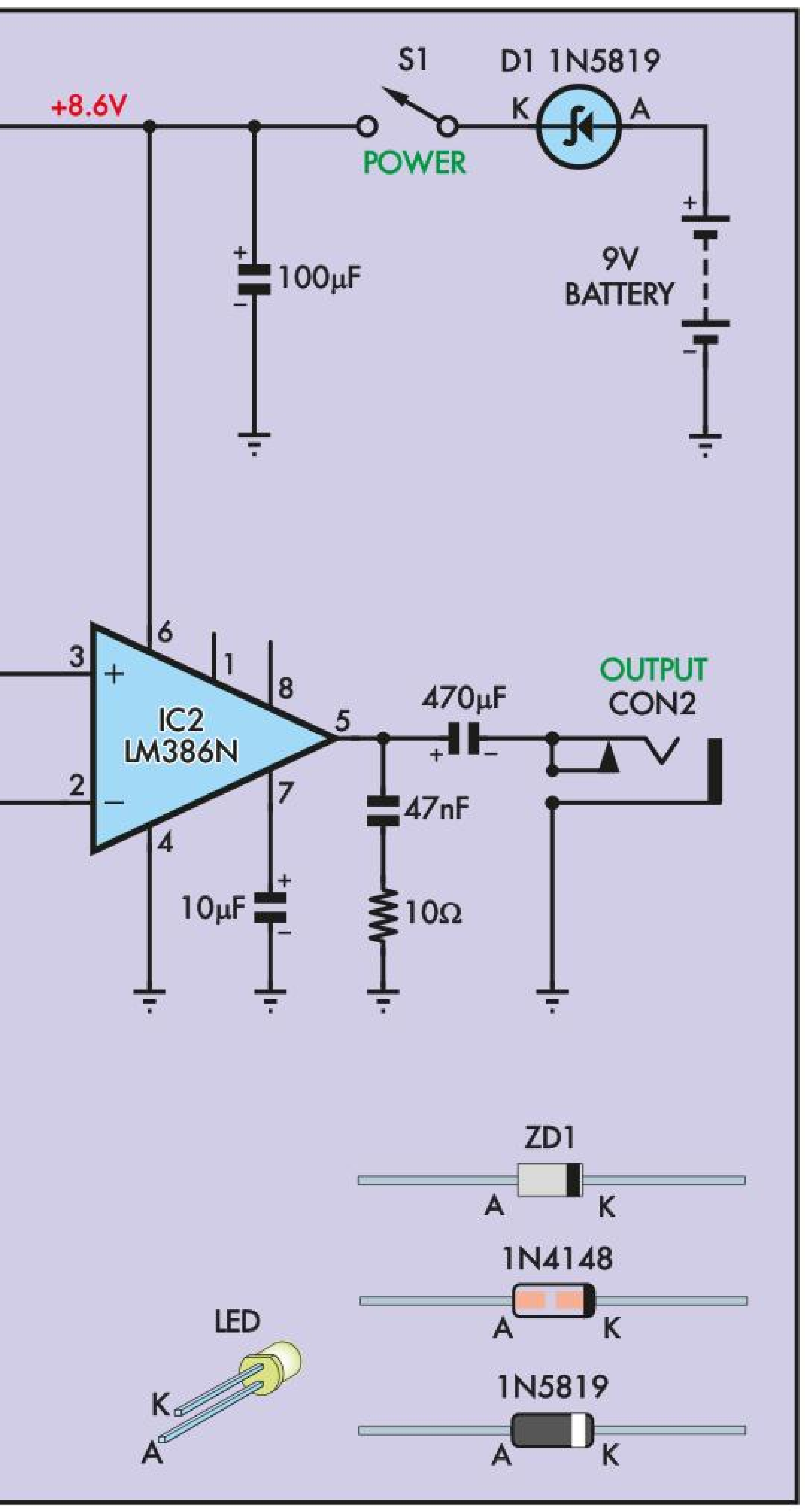
Switchable single-band equaliser

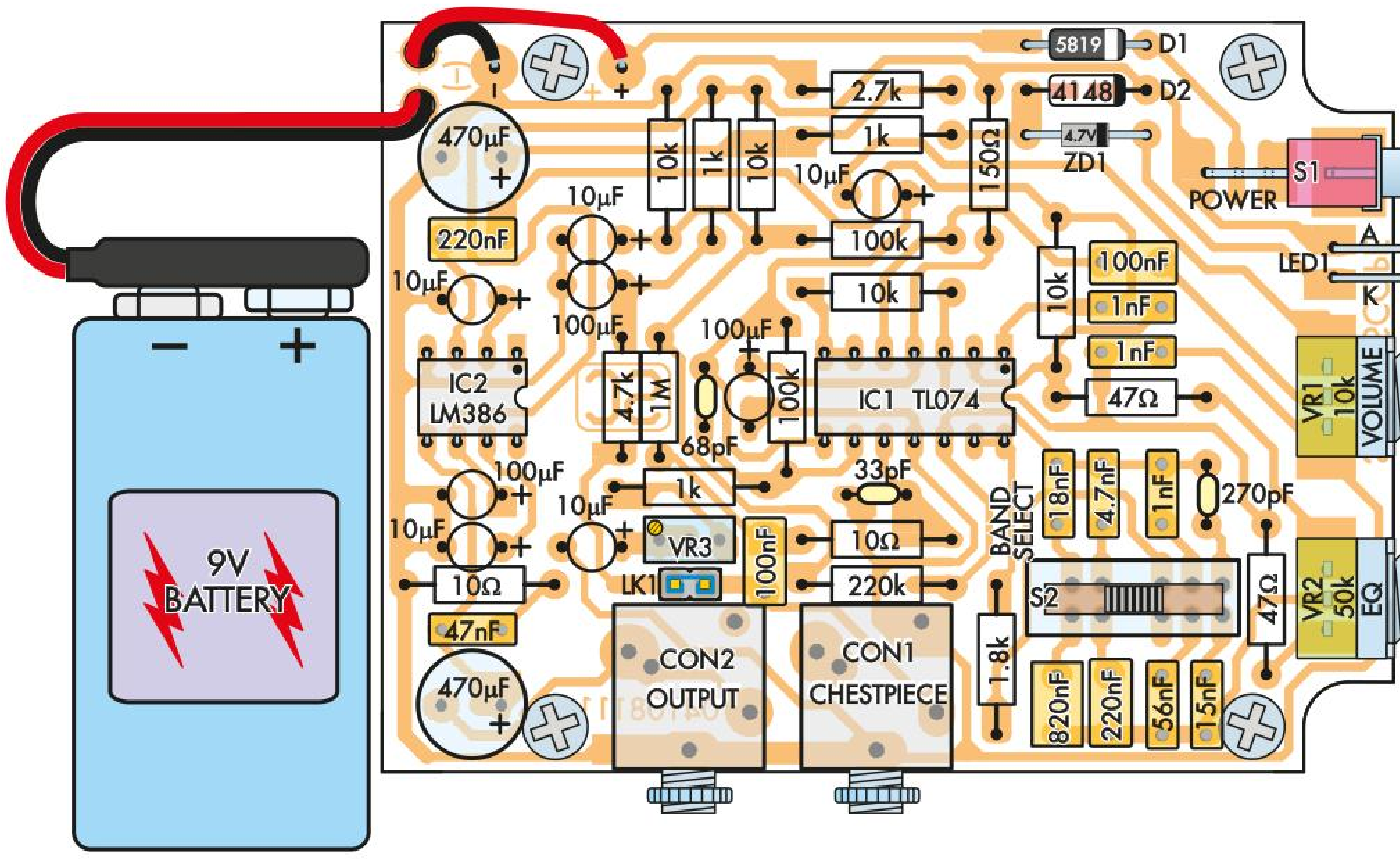
These two op amps form a single-band equaliser, which can boost or cut the signals in a defined frequency band selected by the 4-position slide switch, S2.

The concept for the single-band equaliser can be seen in Fig.2. In essence, we have an op amp (IC1a) connected as a non-inverting amplifier

SPECIFICATIONS

Supply voltage	9V @ 12mA quiescent current
Battery life	Typically 30 hours (with alkaline battery)
Selectable bands	63Hz, 250Hz, 1kHz and 4kHz
Boost or cut range ...	±15dB


S1
D1 1N5819
K
A
+8.6V
POWER
100µF
9V
BATTERY
3
2
6
1
8
5
7
4
IC2
LM386N
470µF
OUTPUT
CON2
47nF
10µF
10Ω
ZD1
A
K
1N4148
A
K
LED
K
A
1N5819
A
K


D1
5819
4148
D2
4.7V
ZD1
2.7k
1k
10k
1k
10k
150Ω
470µF
10µF
10µF
100k
10k
220nF
10µF
100µF
100µF
S1
POWER
LED1
A
K
100nF
1nF
1nF
47Ω
IC2
LM386
4.7k
1M
100k
IC1 TL074
VR1
10k
VOLUME
68pF
33pF
100µF
1k
10µF
10µF
VR3
LK1
100nF
10Ω
220k
BAND SELECT
18nF
4.7nF
1nF
270pF
S2
47Ω
VR2
50k
EQ
10Ω
47nF
470µF
CON2
OUTPUT
CON1
CHESTPIECE
1.8k
820nF
220nF
56nF
15nF
9V
BATTERY
−
+

Fig,4: here's how it all goes together on the PCB. Note how the twin wires from the battery snap pass through the front of the board and back out again – that's for strain relief of the solder joints (they could otherwise snap off). Watch the IC, LED and electrolytic capacitor orientation; also make sure the two pots aren't mixed up. Finally, the jumper for the link (LK1) is only placed in position for use with an electret microphone – it is not used at all for the 'normal' piezo version.

and a feedback network with a potentiometer (VR2) which sets the amount of boost or cut. The frequency band is defined by the resonant frequency of the series-connected capacitor C1, and inductor L1.

With VR2 wound fully to the left, the tuned series LC circuit is connected to IC1a's input via a 47Ω resistor. At the resonant frequency, the impedance of the *LC* network is at a minimum. Thus, the signal applied to IC1a will be shunted to ground, reducing the signal at the IC1a output.

When VR2 is rotated to its Boost setting, the *LC* network is connected directly to the inverting (–) input of the op amp via another 47Ω resistor, shunting the negative feedback to ground. At the resonant frequency, the low impedance of the *LC* network reduces the feedback and the gain of IC1a will increase. The centre frequency equation is given by:

$$F_0 = \frac{1}{2\pi\sqrt{L\,C_1}}$$

In fact, our circuit does not use an inductor in the equaliser, as it would be very large and bulky. Instead, we have replaced the inductor with a gyrator. A 'gyrator' is a pseudo-inductor using an op amp and a capacitor, as shown in Fig.3.

In an inductor, the current lags or is delayed by 90° with respect to the voltage waveform. With a capacitor, however, the voltage lags the current by 90°.

Inductor simulation

To simulate the inductor, the voltage lag of the capacitor must be converted to a leading voltage compared to the current. With an AC signal applied to the input of the circuit (Vin) of Fig.3, current (Iin) will flow through capacitor C2 and the resistor R2.

Because it is connected as a voltage follower, the op amp will reproduce the voltage across R2 at its output.

This voltage will now cause a current to flow in R1 and this adds to the input current. The resulting total current lags the input voltage by 90°. So as far as the signal source is concerned, the circuit behaves like an inductor.

The value of simulated inductance is given by the equation: L = R1 × R2 × C2. By substituting the gyrator for the inductor in the circuit of Fig.2, we have the basis for a complete equaliser.

The 4-position slide switch, S1, selects different values for C1 and C2 for each of the frequency bands.

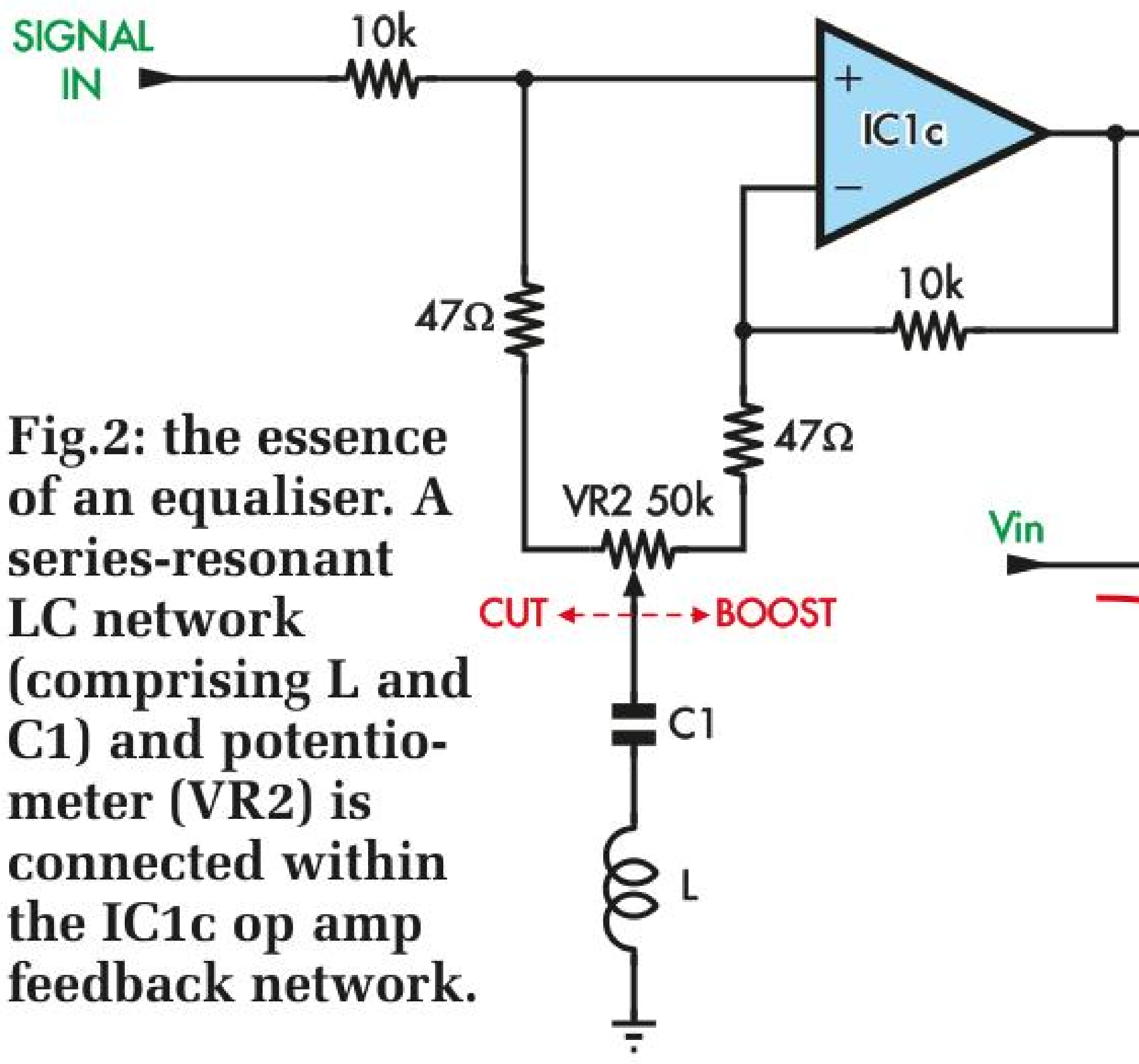

SIGNAL
IN
10k
+
IC1c
−
SIGNAL
OUT
10k
47Ω
47Ω
VR2 50k
CUT
BOOST
C1
L

Fig.2: the essence of an equaliser. A series-resonant LC network (comprising L and C1) and potentiometer (VR2) is connected within the IC1c op amp feedback network.

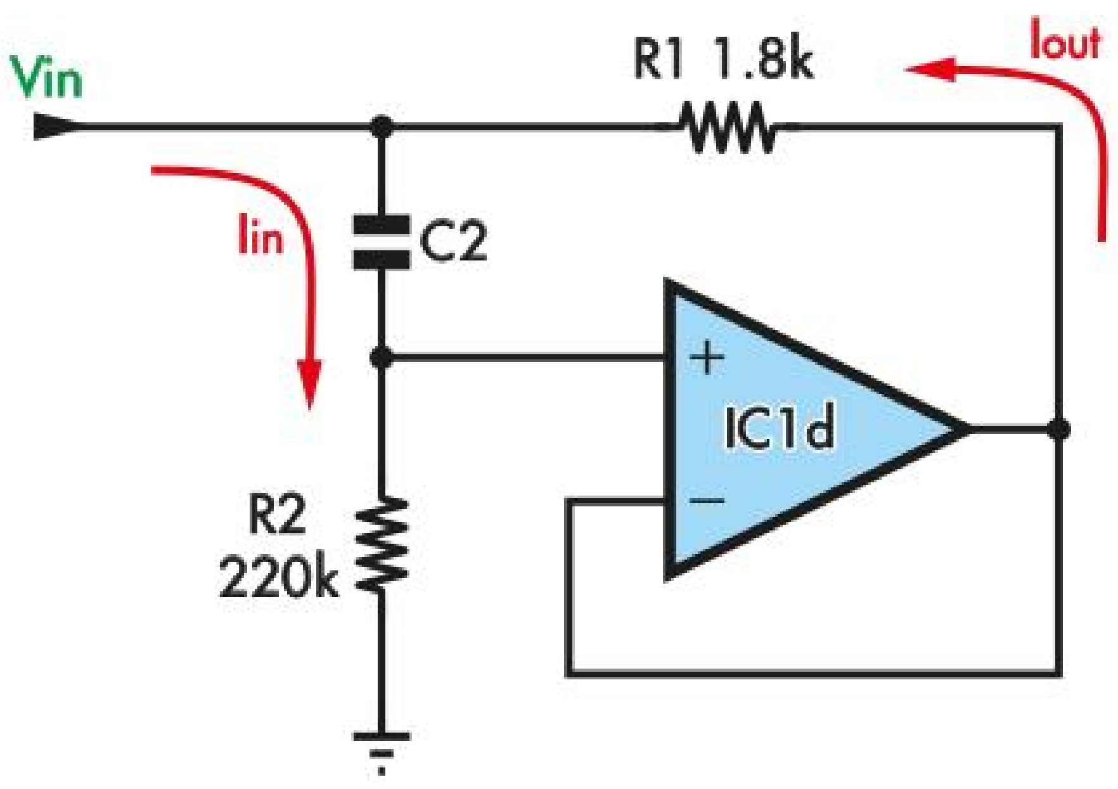
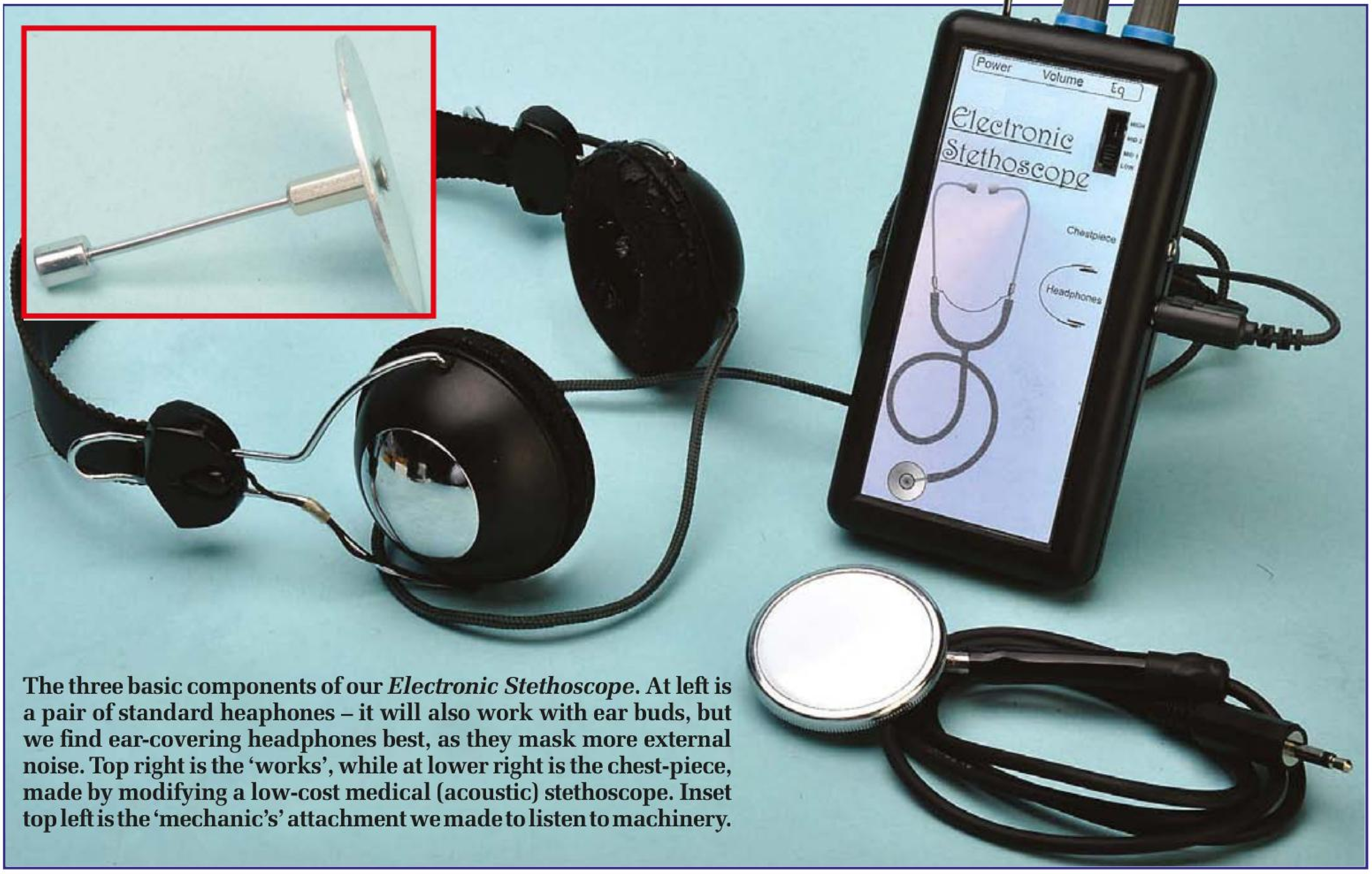

Vin
R1 1.8k
Iout
Iin
C2
+
IC1d
−
R2
220k

Fig.3 (left): circuitry of a gyrator. The op amp IC1d simulates an inductor by a phase transformation of the current through C2. The resulting inductance is equal to the product of R1, R2 and C2.



The three basic components of our *Electronic Stethoscope*. At left is a pair of standard heaphones – it will also work with ear buds, but we find ear-covering headphones best, as they mask more external noise. Top right is the 'works', while at lower right is the chest-piece, made by modifying a low-cost medical (acoustic) stethoscope. Inset top left is the 'mechanic's' attachment we made to listen to machinery.

Following the equaliser stage, the signal is fed via a 220nF capacitor to the non-inverting input (pin 3) of IC2, the LM386 audio power amplifier. IC2 can provide about 500mW into 8Ω with a 9V supply, and distortion is typically 0.2%. When using stereo 32Ω headphones (with the earpieces connected in parallel to give a 16Ω load), the power is about 250mW; more than enough to provide sufficient listening volume.

Power amp IC2 drives the output load via a 470μF capacitor and a Zobel network, comprising a 10Ω resistor and 47nF capacitor, which helps prevent amplifier instability.

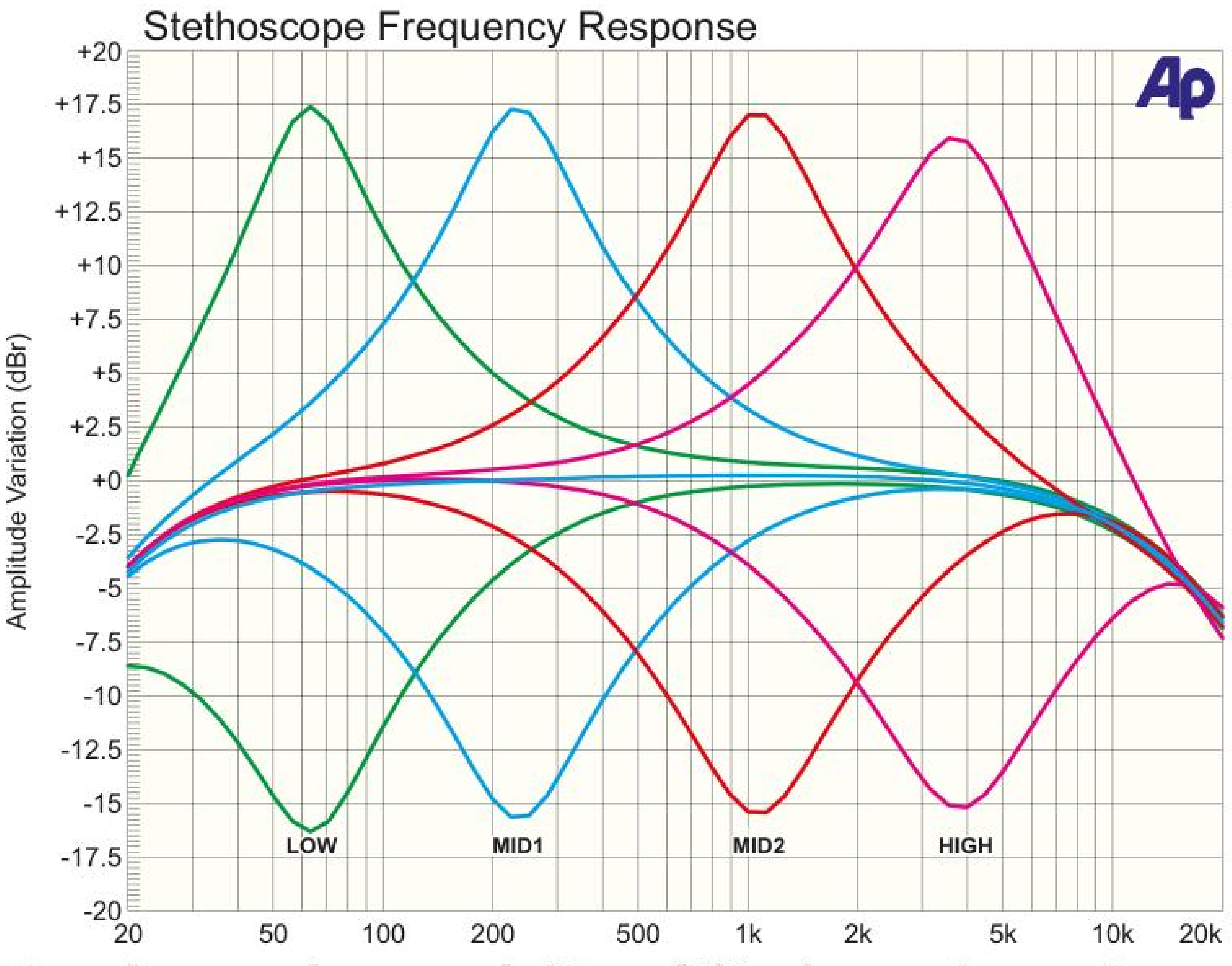


Fig.5: boost and cut graph for each band as set for maximum boost and cut. Note that only one single band can be used at any one time in either boost or cut position. Boost or cut can be set to any level between the two extreme boost or cut levels.

Power supply

The power for the *Stethoscope* comes from a 9V alkaline battery, with diode D1 providing protection against a reverse polarity connection. A Schottky diode is used because of its low forward voltage loss (about 0.3V compared to a normal silicon diode's 0.6V).

LED1 has two functions: to show power 'on' and to show battery condition. It operates as follows. When power is first applied, current for the LED flows through the 4.7V Zener diode (ZD1), the 1kΩ resistor and the discharged 470μF capacitor. If the battery is fresh, the 9V battery provides 8.7V at the anode (A) of LED1. This voltage is reduced by about 1.8V by LED1 and 4.7V by ZD1, leaving 2.2V across the 1kΩ resistor. LED1 lights with 2.2mA.

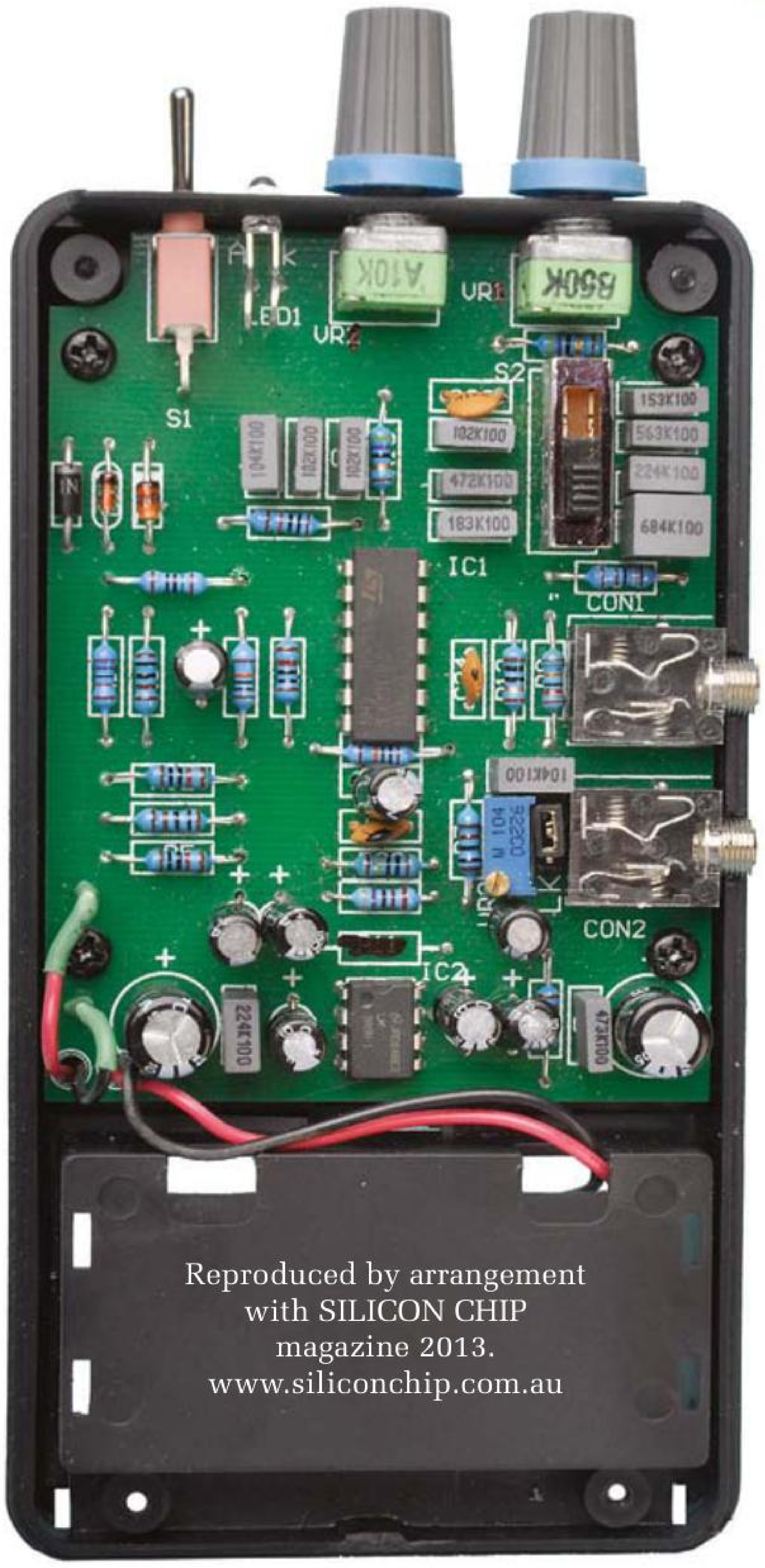
At lower battery voltages, there is less voltage across the 1kΩ resistor, so the LED is dim. At a battery voltage of 7V, there is about 0.2V across the 1kΩ resistor and the LED barely lights.

As the 470μF capacitor charges up, the LED current is reduced to a much lower level, set by the 2.7kΩ resistor across the capacitor. This indicates that the *Electronic Stethoscope* is switched on without wasting significant power. When power is switched off, diode D2 discharges the 470μF capacitor so the circuit is again ready to indicate the battery charge state when it is turned back on.

The 8.7V supply is connected directly to IC2, but it is fed to IC1 via a 150Ω resistor. A 100μF capacitor decouples this supply and removes any supply modulation from IC2, which could otherwise cause instability. This would take the form of audible 'motor-boating'.

Construction

With the exception of the piezo mounted on the chestpiece, all the *Electronic Stethoscope* components are accommodated



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Inside the assembled *Electronic Stethoscope* 'works', reproduced here close to same size. Use this in conjunction with the component overlay (Fig.4).

on a single PCB, measuring 65mm × 86mm. In turn, the PCB is housed in a black plastic 'remote control' case measuring 135mm × 70mm × 24mm. This board is available from the *EPE PCB Service*, code 898.

The PCB is designed to mount on the integral mounting bushes within the specified box. Make sure the front edge of the PCB is shaped to the correct outline so it fits into the box. It can be filed to shape if necessary using the PCB outline as a guide.

Board assembly

Begin construction by checking the PCB for breaks in copper tracks or shorts between tracks or pads. Repair any defects, if necessary. Check the sizes of the PCB mounting holes and for the battery leads. These are 3mm in diameter.

The topside component overlay for the PCB is shown in Fig.4 You can start assembly by inserting the resistors. Check each resistor value with a digital multimeter (DMM). Next, install the two PC stakes followed by the diodes, mounted as shown.

IC1 and IC2 can be directly mounted on the PCB, or if you wish can be mounted on IC sockets. When installing ICs (and sockets if you use them), take care to orient them correctly. Orientation is with the notch positioned as shown.

Slide switch S2 does not mount directly on the PCB, but is raised off the PCB using a 6-way dual row pin header. Remove a pair of pins so that there is a row of three pins, then a gap then two pins on each side of the DIL header.

The header pins are longer at the top than the bottom. Push them down so that the tops are 5mm above the bottom of the plastic section and solder it in the switch mounting position. The switch is mounted by soldering its pins to the top of the header pins. The switch must be oriented correctly with the row of three pins toward the volume pot (VR1). The top of the switch body should be 12mm above the PCB.

The capacitors can be mounted now. The electrolytic types must be oriented correctly – the polarity is shown on the component overlay. Make sure these capacitors are placed in the PCB so their height above the board surface is no more than 12.5mm, otherwise the lid of the case will not fit correctly.

The potentiometer (VR2) and the PCB-mounted switch S1 can also be fitted now, along with the 3.5mm jack sockets. LED1 mounts horizontally, but at a height of 6mm above the PCB. Bend its leads at 7mm back from the base of the LEDs at 90°, making sure the anode lead is to the left.

Casing up

When assembled, the PCB is secured to the base of the case using four M3 × 6mm screws that screw into the integral mounting bushes in the box. Before putting this in place, drill out the small front panel for the LEDs, potentiometer and switch. A drill guide is provided with the front panel label.

Holes are also required in the base and case lid for the 3.5mm sockets. Use a rat-tail file to make these cut outs. The panel label for this project can be downloaded from the *EPE* website (www.epemag3.com/projects.html). Select the month and year of publication.

When downloaded, you can print onto paper, sticky-backed photo paper or plastic film. Paper labels need protection, so cover them with self-adhesive clear plastic or, best of all, hot laminate film.

When using clear plastic film (overhead projector film) you can print the label as a mirror image so that the ink is behind the film when placed on the panel. Once the ink is dry, cut the label to size.

The paper or plastic film version is glued to the panel using an even smear of neutral cure silicone sealant or spray contact adhesive. If you are glueing a clear plastic film label to a black coloured panel, use coloured silicone such as grey or white so the label can be seen against the black.

End-on view showing the three controls (Eq, Volume and Power) on the end panel and the four-way filter band selection switch on the front panel.

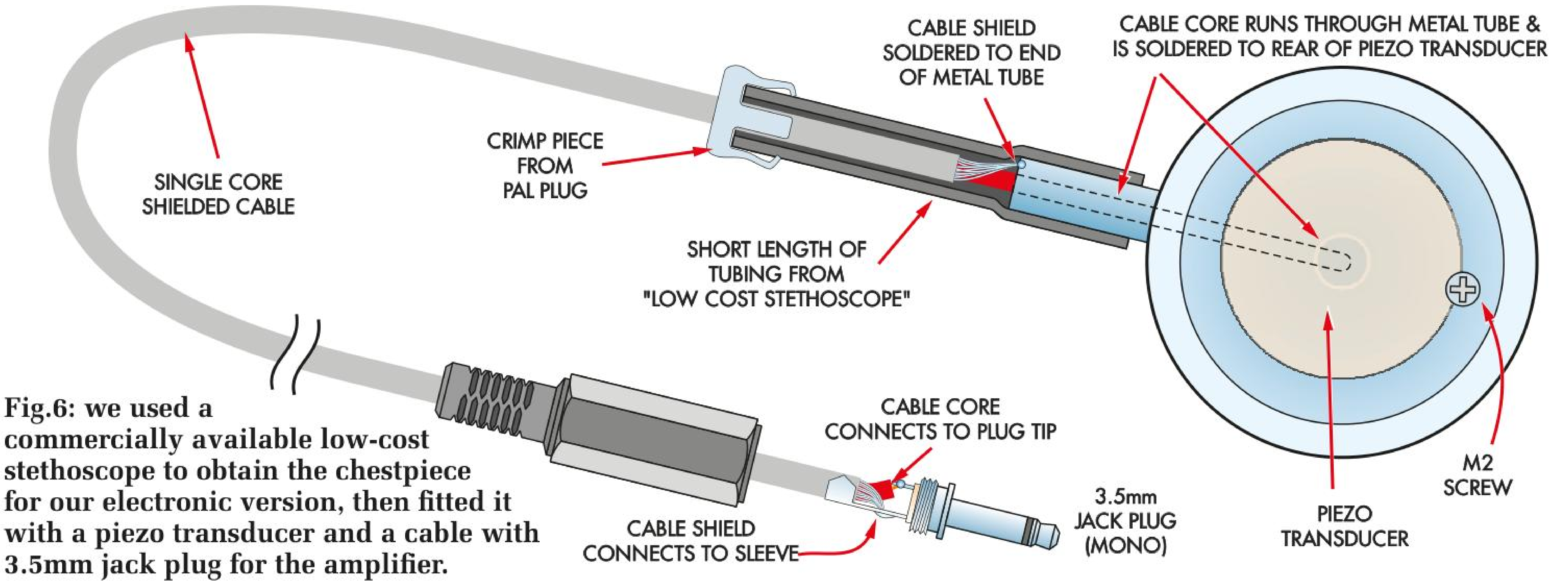

SINGLE CORE SHIELDED CABLE
CRIMP PIECE FROM PAL PLUG
CABLE SHIELD SOLDERED TO END OF METAL TUBE
CABLE CORE RUNS THROUGH METAL TUBE & IS SOLDERED TO REAR OF PIEZO TRANSDUCER
SHORT LENGTH OF TUBING FROM "LOW COST STETHOSCOPE"
CABLE CORE CONNECTS TO PLUG TIP
CABLE SHIELD CONNECTS TO SLEEVE
3.5mm JACK PLUG (MONO)
PIEZO TRANSDUCER
M2 SCREW

Fig.6: we used a commercially available low-cost stethoscope to obtain the chestpiece for our electronic version, then fitted it with a piezo transducer and a cable with 3.5mm jack plug for the amplifier.

A rectangular hole in the panel is required directly above the slider switch S2. The positioning for this is shown on the label – see also large composite photograph. This shape can be first drilled in the plastic lid and then once the panel label is affixed, cut the panel hole out using a sharp hobby knife. The top of the switch can be coloured black using a permanent marker pen to improve the appearance through the switch hole.

Chestpiece

The ‘chestpiece’ for the *Stethoscope* is cannibalised from a commonly-available (and low-cost) acoustic medical stethoscope. Ours came from Jaycar Electronics (www.jaycar.com.au), cat no QM7255, but most chemists and medical supply houses have them. You can pay a lot more for a stethoscope – for example the Littman Cardiology III, manufactured by 3M, sells for more than £100. But we’re not interested in specialised models, an ordinary stethoscope is what we’re after.

The following applies specifically to the Jaycar model, but you will probably find that most of the low-cost stethoscopes use a similar method of construction.

The diaphragm section is removed from the chestpiece to access the inside of the casting. Unscrewing the outer annulus from the rear casting does this.

The piezo element (disk) from a piezo transducer is used as the detector and is placed within the chestpiece diecast housing.

We did test the stethoscope using an electret microphone insert for the chestpiece pickup sensor. This was a very small microphone at 6mm in diameter and 3.5mm deep that sat within the back of the diecast moulding. This proved to be unsatisfactory for this application, although there was nothing wrong with the microphone itself.

The main problem was that it would detect far more than was required for a stethoscope, including noises from adjacent rooms. The use of an electret microphone, however, is ideal for use as an eavesdropper. See the separate section concerning its use.

Piezo element

A piezo element produced a much better result. The piezo element is removed from its plastic transducer housing. To do this, remove the backing piece from the housing to expose the transducer. The transducer is easily prised out as it is glued to the housing with a soft rubber-based adhesive. Take care not to crack the piezo element.

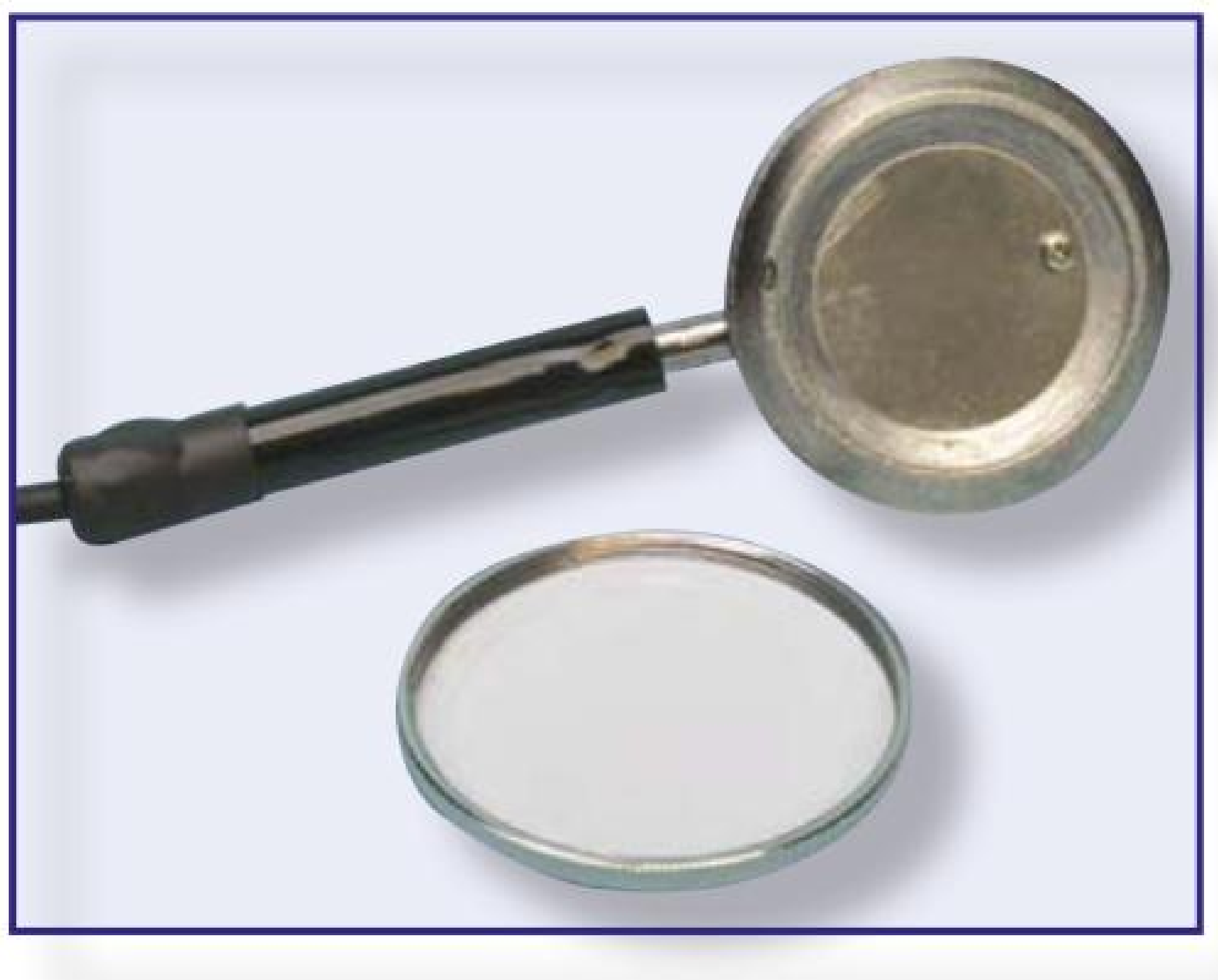
Wires connected to the transducer are removed by melting the solder from the metal disc and piezo element itself. Remove the solder with some solder wick.

The piezo element is attached to the chestpiece using an M2 × 3mm screw that is tapped into the chestpiece casting. Drill a 2mm hole in the edge of the transducer but *away* from the piezo material itself and align the transducer central to the chestpiece housing.

Mark out where the mounting hole is required. Drill a 1.5mm hole (1/16-inch) and screw the M2 screw into the hole. You may need to file a small notch along the M2 screw thread to act as a makeshift thread cutter if the screw does not enter the hole easily. (Of course, if you happen to have an M2 tap, use that.)

Once the hole is ‘tapped’, remove the screw. The piezo sensor is placed on the chestpiece housing with the piezo element facing inward.

The core wire of the shielded cable passes through the metal tubing of the chestpiece and is soldered to the centre of the piezo element. The shielding wire is soldered to the end of the metal tube after first filing out a small flat landing



These three photos show, respectively (from left) the disassembled chest piece with the piezo fitted; the reassembled chestpiece with the cable going off to the amplifier fitted into a short length of the tubing from the original stethoscope and finally, a close-up of the ‘clamp’ (actually the wire clamp from a TV cable plug) used to hold it all together.

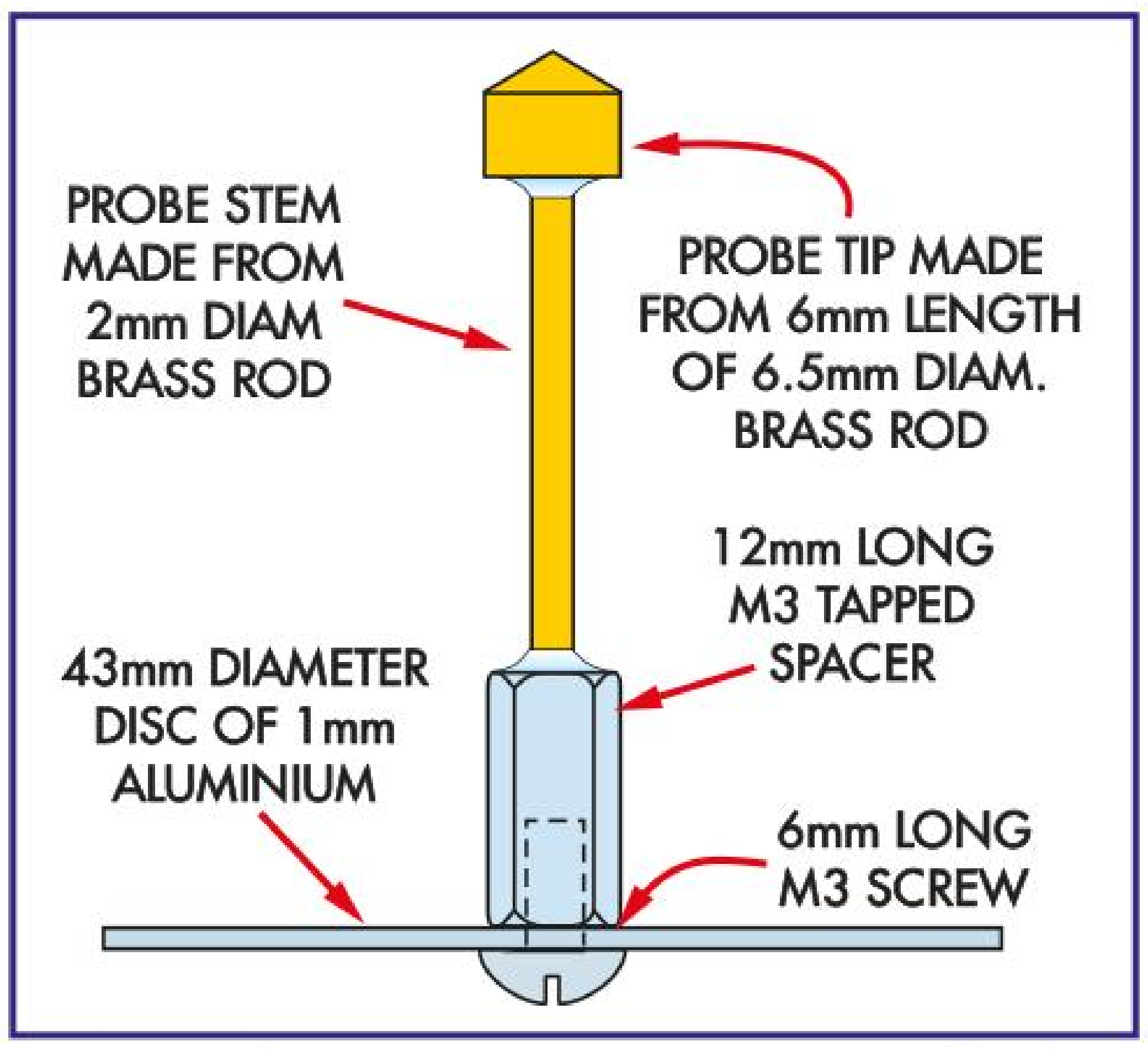

PROBE STEM MADE FROM 2mm DIAM BRASS ROD
PROBE TIP MADE FROM 6mm LENGTH OF 6.5mm DIAM. BRASS ROD
12mm LONG M3 TAPPED SPACER
43mm DIAMETER DISC OF 1mm ALUMINIUM
6mm LONG M3 SCREW

Fig. 7: to listen to engine noise and other equipment you'll need something like this probe. It transmits vibrations direct to the piezo transducer of the chestpiece.

on the side of the tubing to allow for a solder joint. Secure the transducer with the M2 screw. A smear of neutral cure silicone sealant (eg, roof and gutter sealant) is applied around the outside of the transducer to form an air seal to the chestpiece housing.

A short (60mm) length of the tubing from the low-cost stethoscope is cut and slid over the shielded cable and on to the metal tubing of the chestpiece. The tubing is crimped to the shielded cable wire – we used the crimp section of a Coax TV aerial plug placed over the tubing.

This is squeezed down over the tubing to grip the shielded cable in place within the tubing. A 20mm length of 10mm diameter heatshrink tubing is shrunk down over the section to hold the crimp 'fingers' closed.

The diaphragm and annulus can now be reattached to the chestpiece housing by screwing this back together. The opposite end of the shielded cable is terminated to a 3.5mm mono jack plug.

Mechanic's attachment

For the mechanic's attachment, we used a 43mm diameter disc of 1mm aluminium to replace the flexible diaphragm of the chestpiece. This means that the annulus is unscrewed and the flexible diaphragm removed by pressing it out with your fingers.

A rod attaches through the centre of this aluminium disc to provide contact with the machinery. We supported our rod using an M3 tapped brass spacer secured to the disc with an M3 × 6mm screw. To this spacer is soldered a brass rod with a tipped end (see Fig.7).

We used the end from a discarded telescopic antenna for the rod and soldered this to the 12mm spacer. The rod is 60mm long, but it could be longer than that if you need it to be.

Parts List – Electronic Stethoscope

1 PCB, coded 898, available from the *EPE PCB Service*, size 65mm × 86mm
1 remote control case 135mm × 70mm × 24mm (Jaycar HB5610 or equivalent)
1 panel label 50mm × 114mm
1 9V battery
1 9V battery clip lead
1 low-cost stethoscope (Jaycar QM7255) used for parts
1 miniature PC mount SPDT toggle switch (S1)
1 DP4T switch (Tyco Electronics STS2400PC04) (Element14 Cat.1291137) (S2)
2 knobs to suit potentiometers
2 PC mount 3.5mm stereo sockets (CON1,CON2)
1 3.5mm mono line jack plug
1 8-pin IC socket (optional)
1 14-pin IC socket (optional)
1 piezo transducer
1 TV aerial coax line plug, with plastic housing (required for the metal crimp shield connector)
4 M3 × 6mm screws
1 M2 × 3mm screw (or a cut down M2 × 8mm screw)
1 6-way DIL pin header
1 2-way pin header with 2.54mm spacing (with jumper shunt)
2 PC stakes
1 60mm length of 10mm diameter heatshrink tubing
1 750mm length of single core shielded cable

Semiconductors
1 TL074 quad op amp (IC1)
1 LM386N amplifier (IC2)
1 1N5819 1A Schottky diode (D1)
1 1N4148 switching diode (D2)
1 4.7V 1W Zener diode (ZD1)
1 3mm high intensity red LED (LED1)

Capacitors
2 470µF 16V PC electrolytic
3 100µF 16V PC electrolytic
5 10µF 16V PC electrolytic
1 820nF MKT polyester
2 220nF MKT polyester
2 100nF MKT polyester
1 56nF MKT polyester
1 47nF MKT polyester
1 18nF MKT polyester
1 15nF MKT polyester
1 4.7nF MKT polyester
3 1nF MKT polyester
1 270pF ceramic
1 68pF ceramic
1 33pF ceramic

Resistors (0.25W, 1%)
1 1MΩ 1 220kΩ 2 100kΩ
4 10kΩ 1 4.7kΩ 1 2.7kΩ
1 1.8kΩ 3 1kΩ 1 150Ω
2 47Ω 2 10Ω
1 10k log potentiometer, 9mm square, PCB mount (VR1)
1 50k linear potentiometer, 9mm square, PCB mount (VR2)
1 100kΩ multiturn top adjust trimpot (VR3)

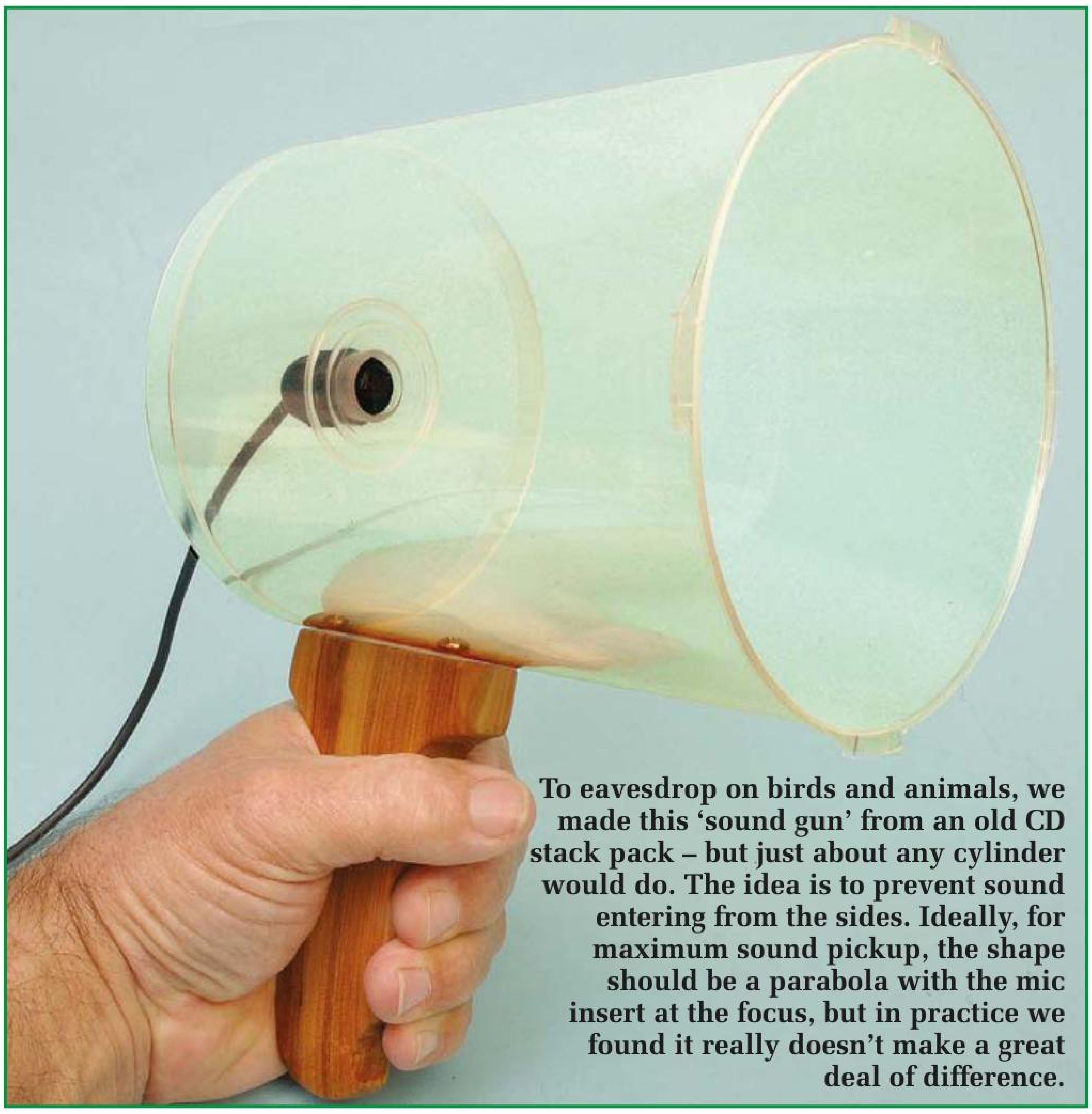
Miscellaneous
Earphones or headphones, neutral cure silicone sealant, solder.

Mechanic's Stethoscope – Optional Parts

1 43mm diameter circle of 1mm aluminium
1 M3 × 12mm tapped brass spacer
1 M3 × 6mm countersunk screw
1 brass rod 2mm diameter × 40mm long with a 6mm brass spacer tip *or*
1 top end from a telescopic antenna

Audio Eavesdropper – Optional Parts

1 electret microphone insert (9.5mm diameter) (Jaycar AM-4010 or sim)
1 300mm length of single-core shielded cable
1 3.5mm mono line plug
1 IP68 waterproof gland for 4 to 8mm diameter cable
1 plastic cylinder 125ID × 157mm long (eg empty 100 × CD container) or similar (see text)
1 timber handle 65 × 115mm (eg, pine off cuts or similar)
2 wood screws (to secure handle)



To eavesdrop on birds and animals, we made this 'sound gun' from an old CD stack pack – but just about any cylinder would do. The idea is to prevent sound entering from the sides. Ideally, for maximum sound pickup, the shape should be a parabola with the mic insert at the focus, but in practice we found it really doesn't make a great deal of difference.

An alternative tip could be made from a length of 2mm diameter brass rod and a 6mm long brass standoff. These parts are then soldered together.

The aluminium disc is held in place using the anulus in the same way as the diaphragm.

Testing

Test with the 9V battery connected. Apply power and check that the power LED momentarily lights brightly when switched on and then dims.

Wind the VR1 volume control fully anticlockwise and set the tone control to mid position. This will prevent IC2 from producing large signal levels with no input connected. This allows DC voltages to be tested without being masked by a large AC signal.

For a 9V battery supply, we measured 8.7V at the cathode (K) of D1, 7.7V at pin 4 of IC1 and 8.7V at pin 6 of IC2, with the multimeter's negative probe connected to the casing of one of the 3.5mm jack sockets. A half supply voltage of around 4.3V should be found at pins 1, 7, 8 and 14 of IC1, and at pin 5 of IC2.

Ensure the jumper link (LK1) for the electret microphone bias is not inserted for the piezo element of the chestpiece.

Connect the chestpiece and headphones or earpieces to the *Stethoscope*. Set the volume about mid way and adjust preset VR3 for a suitable level of volume, when monitoring the heart beat on the left side of your chest. Rotate VR3 clockwise for more gain and anticlockwise for less gain.

Check that the tone can be adjusted to boost and cut the selected band of frequencies. This will be evident on the low setting as the heart beat thump is boosted or cut. On the high band, more hissing sound will be produced on boost, but reduced on cut.

For an idea of what various body sounds make, log onto **www.easyauscultation.com**. You can then try and find those sounds using your *Electronic Stethoscope*.

Audio eavesdropper

The *Electronic Stethoscope* can be used to monitor sounds from a distance using an electret microphone mounted in an open-ended container instead of the piezo element within the chestpiece. With this setup you can listen to bird or animal calls (or virtually anything else) at a distance.

The container provides directional sound response, where sound enters the open-ended container to be received by the microphone.

Sounds coming from the side and rear of the container are reduced in level before reaching the microphone.

Our CD pack sound gun

Construction of our 'sound gun' is straightforward and is shown in the

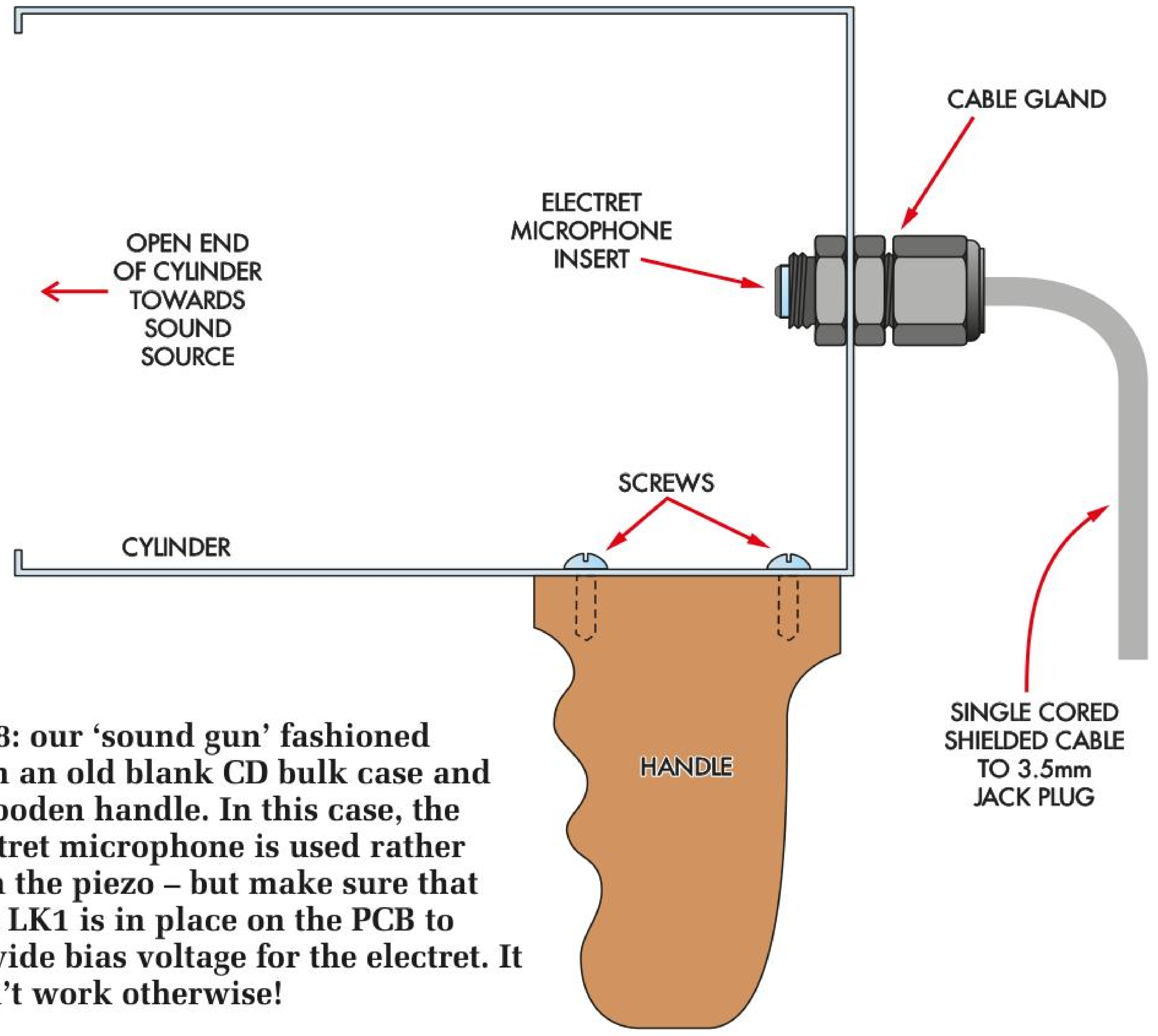

CABLE GLAND
ELECTRET MICROPHONE INSERT
OPEN END OF CYLINDER TOWARDS SOUND SOURCE
SCREWS
CYLINDER
HANDLE
SINGLE CORED SHIELDED CABLE TO 3.5mm JACK PLUG

Fig.8: our 'sound gun' fashioned from an old blank CD bulk case and a wooden handle. In this case, the electret microphone is used rather than the piezo – but make sure that link LK1 is in place on the PCB to provide bias voltage for the electret. It won't work otherwise!

photo and Fig.8. It's not at all critical – use whatever is available.

The cylinder's closed end is drilled out to accept the IP68 gland. This gland neatly houses the electret, while the clamp end secures the shielded cable.

Strip the ends of the shreened cable and solder the wires of one end to the microphone insert connection pads. The shielded wires (mesh) connect to the insert's case pad and the inner wire to the other pad.

The opposite wire end passes through the gland and is clamped down with the electret inserted into the open-gland end. The wire is then terminated to a 3.5mm mono jack plug.

A handle was fashioned from an off-cut of timber (we reshaped the decorative top section of a cyprus pine picket) and secured this to the side of the plastic cylinder with self-tapping screws. The shape of the handle is not critical so long as it is comfortable to hold. The handle can be finished with olive oil rubbed into the timber before wiping off the excess.

The unit is now ready to test. Plug into the *Electronic Stethoscope* and note that for this application (or any other using the electret microphone), the electret bias needs to be selected by inserting link LK1.

A parabola?

For maximum concentration of sound at the microphone, a parabolic dish should be used with the microphone mounted at the focal point.

We've used a number of different parabolic or near-parabolic shaped dishes in the past.

Design of the pickup using a 'parabolic' shaped dish and electret microphone is shown in the Ultrasonic Eavesdropper article from August 2008 by Jim Rowe. While that design was to receive ultrasonic sounds and convert them to the normal audio band, the pickup arrangement is the same for the audio sound band.

One alternative parabola which we haven't tried (but should be near perfect!) is a metal cooking wok, available quite cheaply from oriental food suppliers. To find the focal point, shine a single-point light source (eg, an LED) into the wok along its centre line. As you move it in and out, at one point the light will appear to 'fill the dish' – that's the focal point. We'll leave the mechanical arrangement for mounting the microphone up to you. ***EPE***

Designing your own single-band equaliser

While most users will be satisfied with the four frequency bands selected for the equaliser, there may be some who require different bands. To satisfy this, we have included a method to design your own equaliser section.

Fig.9 shows the typical bandwidth of an equaliser section under boost. The centre of the band is designated F_0, while the frequencies where the response is 3dB down from the F_0 level are shown as F_1 and F_2.

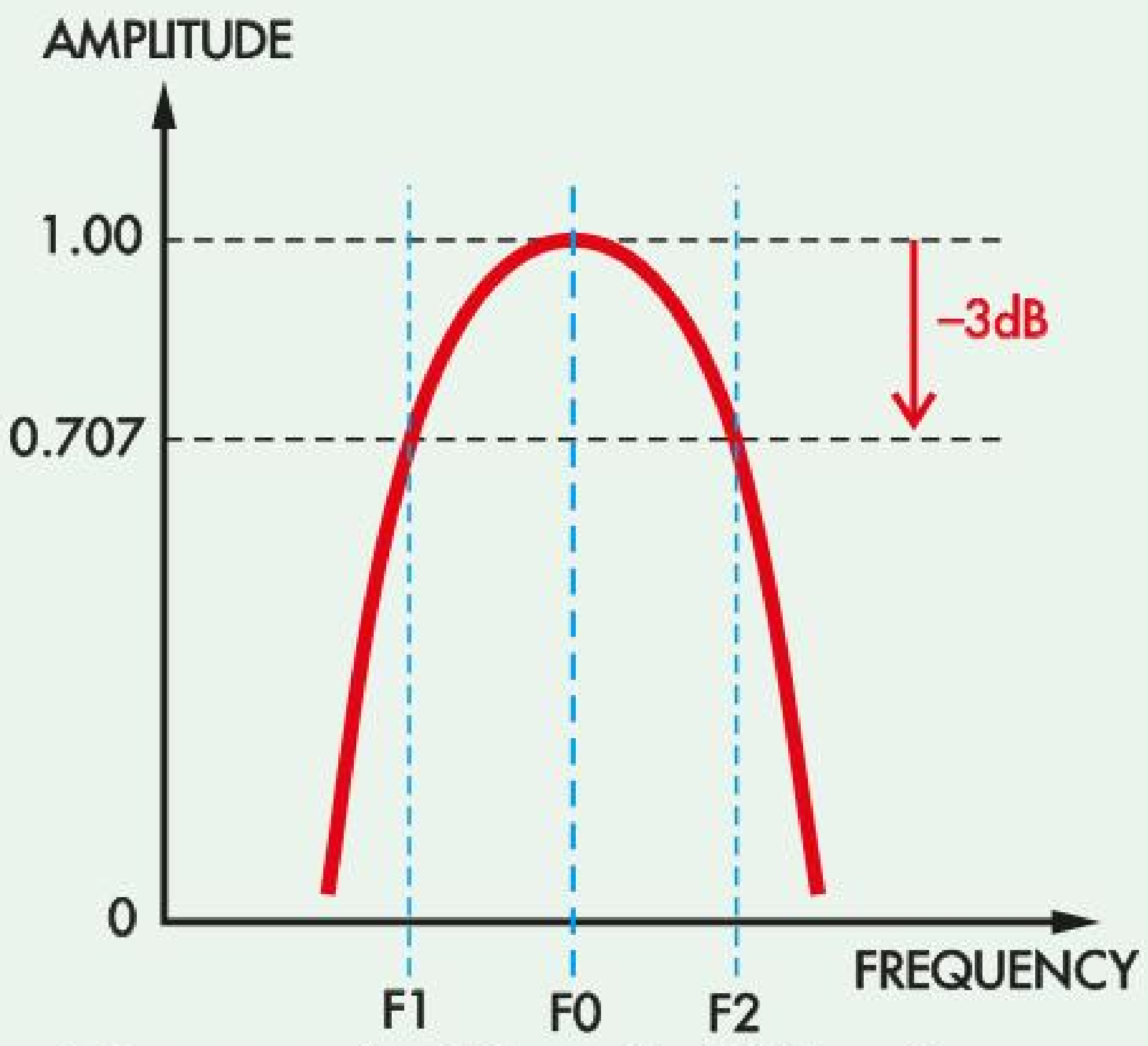


Fig.9: typical bandwidth of an equaliser section under boost.

To design for a particular frequency band you can use the equation:

$$L = \frac{1}{4\pi^2 C_1 F_0^2}$$

This is to obtain a value for the inductance L, using selected values for C1 and F_0. The equation is just a rearrangement of the standard

$$F_0 = \frac{1}{2\pi \sqrt{L C_1}}$$

Knowing the inductance enables us to calculate the required value for C_L. Use the equation:

$$C_L = \frac{L}{R_1 R_2}$$

For our circuit we used a 1.8kΩ resistance for R_1 and 220kΩ resistance for R_2. The Q of the circuit determines the two frequencies either side of F_0 where the signal drops off in level by 3dB. You can calculate the Q using this equation:

$$Q = \frac{2\pi F_0 L}{R_1}$$

The Q is also found using the equation

$$Q = \frac{F_0}{F_2 - F_1}$$

although the equations to find F_1 and F_2 are more difficult. A useful calculator to find F_1 and F_2 is at:

www.sengpielaudio.com/calculator-cutoffFrequencies.htm

The tables below show the components used in the *Stethoscope*, the inductance, Q and F_1 and F_2 for the four bands. You can use these values to practise calculating the values for L and C_2.

F_0	C_L	R_1	R_2	C_1
63Hz	18nF	1.8kΩ	220kΩ	820nF
250Hz	4.7nF	1.8kΩ	220kΩ	220nF
1kHz	1nF	1.8kΩ	220kΩ	56nF
4kHz	270pF	1.8kΩ	220kΩ	15nF

Required F_0	Calculated F_0	Q	F_1	F_2	L
63Hz	65Hz	1.62	48Hz	88Hz	7.13H
250Hz	248Hz	1.61	188Hz	337Hz	1.86H
1kHz	1068Hz	1.49	768Hz	1485Hz	396mH
4kHz	3.974kHz	1.53	2.882kHz	5.479kHz	107mH

TechnoTalk

From Wi-Fi to Li-Fi

Mark Nelson

Any new invention that doubles (or trebles) the bang for your buck deserves serious investigation. The fact that Britain is leading the practical development in one is a welcome bonus. Mark has the story.

RHYME and alliteration appeal to us Anglo-Saxons for some reason. Actually, 'reduplication' is the technical term for the feature that distinguishes phrases like hanky-panky, okey-dokey, flower power and namby-pamby.

Wi-Fi followed hi-fi (even though there is no special fidelity in Wi-Fi) and the latest coining, by analogy with Wi-Fi, is Li-Fi. And, as you may have already guessed, it is a fast and cheap wirefree communication system, in fact an optical version of Wi-Fi.

Illumination

The name comes from Harald Haas, the pioneer behind a new type of lightbulb that can communicate as well as illuminate, allowing us to access the Internet using light instead of radio waves. Harald, a 23-year-old software developer from Austria, coined the name two years ago after realising that flickering the light from an LED lamp (or a single LED) could transmit far more data than a radio base station – and do it in a way that's more efficient, secure and widespread.

The modulation of the light is far too rapid for the human eye to detect, but it can transmit data at a rate of 10Mbit/s (faster than a typical broadband connection), 100Mbit/s by the end of this year and possibly up to 1Gbit/s in the future.

The system, which he calls D-Light, uses a technique called OFDM (orthogonal frequency-division multiplexing) that varies the intensity of an LED's output at a very fast rate, invisible to the human eye (which just sees a bulb that's on and providing ordinary light). The signal can be picked up by simple receivers. Says Harald, "It should be so cheap that it's everywhere. Using the visible light spectrum, which comes for free, you can piggy-back existing wireless services on the back of lighting equipment."

Observers have noted, that as well as revolutionising Internet reception, it would put an end to the possibly harmful electromagnetic radiation emitted by wireless Internet routers and has raised the prospect of ubiquitous wireless access, transmitted through streetlights. Also, using D-light instead of wireless in airliner cabins, it would avert the risk of passengers' equipment interfering with onboard navigation systems.

Because D-light is optical rather than radio, electronic eavesdropping from one room to another is rendered virtually impossible. Or putting it another way, there would be no risk that your neighbour could see what you were downloading to your home Li-Fi network, nor would your own network suffer interference from others nearby.

Lighting the way

One organisation that takes the D-light notion seriously is the University of Strathclyde, in alliance with four other British centres of learning, which together are aiming to develop innovative technology for unleashing the full potential of Li-Fi.

Although other worldwide bodies are investigating home and office applications of Li-Fi, Strathclyde's Prof Martin Dawson has wider visions, he said: "Imagine an LED array beside a motorway helping to light the road, displaying the latest traffic updates and transmitting Internet information wirelessly to passengers' laptops, netbooks and smartphones. This is the kind of extraordinary, energy-saving parallelism that we believe our pioneering technology could deliver."

Exactly how the light beams would penetrate inside your vehicle is unclear from this description; maybe by light scatter (diversity reception) or else the vehicle would need to be equipped with lightwave antennas, receivers and internal re-transmitters.

Global race

Strathclyde's work is not unique; other teams around the world are also exploring the possibilities. In 2011, German scientists, working with industry partners Siemens and France Telecom Orange Labs, demonstrated an optical local network using normal red, blue, green and white LED lamps. Mounting these on the ceiling gave a coverage of about 10 square metres.

Dr Anagnostis Paraskevopoulos of the Heinrich Hertz Institute explained they could transfer four videos in HD quality to four different laptops at the same time. "With the aid of a special component, the modulator, we turn the LEDs off and on in very rapid succession and transfer the information as ones and zeros. The modulation of the light is imperceptible to the human eye.

A simple photo diode on the laptop acts as a receiver. The diode catches the light, electronics decode the information and translate it into electrical impulses, meaning the language of the computer," he said.

A key difference in the latest research is the size of the LEDs employed. Strathclyde University plans to use much smaller, micron-sized, LEDs, which can turn on and off around 1,000 times faster than standard-size versions. This promises faster data transfers as well as occupying less space.

With each LED able to carry a separate channel, one could aim either for smaller transceiver modules or an increase in the number of communication channels. A large LED array display could act simultaneously as an information display screen, Internet communications portal and source of illumination.

Eventually, it could even be possible for the LEDs to incorporate sensing capabilities too. For example, a mobile phone could be equipped with a flash that – when pointed at a shop display in which every item has been given an electronic price tag – could display the price of these items.

A love-in

Back in the 1990s, BT and other companies were talking about lightwave transmitters mounted on office ceilings for local area networks. The idea was to eliminate the cost of LAN cabling to the desk. The only difference was that these networks would use infra-red radiation rather than visible light. This built on the success of the infra-red links used by computer mice.

An even older application for optical mass-communication was *Radio Love*, which I mentioned in this column back in the April 2003 issue. Radical in more ways than one, and at a time when radio broadcasting was a state monopoly in the UK, the protagonists of *Radio Love* had the idea of getting around this dominance by using light waves.

The plan was to broadcast on optical frequencies, beaming down on London from the top of the Centre Point office block. Listeners in London would have their transistor sets converted with a photo-electric cell and could tune into their choice of music. That was the theory; the reality never came to pass.

EPE EXCLUSIVE

Win one of THREE Microchip F1 Evaluation Kits

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip *F1 Evaluation Kit*, containing an F1 Evaluation Platform and PICkit 3. The F1 Evaluation Platform is a simple development tool for enhanced mid-range PIC microcontrollers (PIC12F1XXX/PIC16F1XXX) and demonstrates the capabilities and low-power enhancements of these new PIC microcontrollers. Including a PICkit3 for quick programming, this kit provides a platform for general purpose development and gives you the ability to develop code for any PIC12F1XXX/PIC16F1XXX microcontroller.

Quick and easy development is ensured with integrated functionality, including: • prototyping area • LCD control • system current monitoring • temperature sensing • real-time clock • LED drive • button control • BLDC motor control.

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- Platform and demonstration guide, source code for included demonstrations and board schematics.

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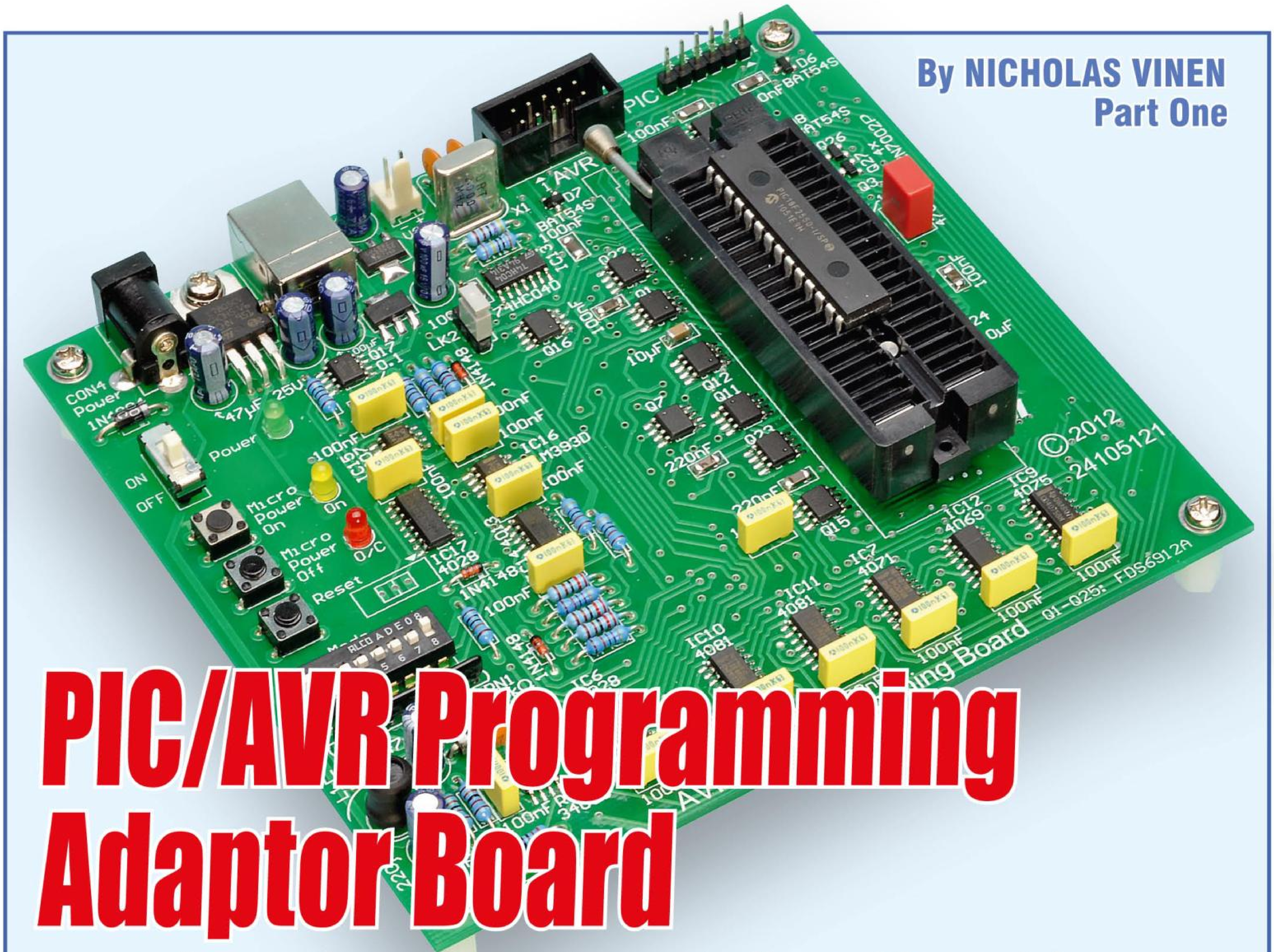
By NICHOLAS VINEN

Part One



PIC/AVR Programming Adaptor Board

Do you frequently program microcontrollers with a serial programmer? Want to streamline the process so you can quickly do virtually any micro?

Well now you can! Our new Programming Adaptor Board, in combination with an in-circuit serial programmer (ICSP), allows you to program most 8-bit and 16-bit PIC microcontrollers, as well as 8-bit Atmel AVRs.

MOST embedded developers program their microcontrollers using an in-circuit serial programmer such as the Microchip PICkit 3 or the Atmel AVRISP MkII. These plug into the USB port on your PC and a header on the development board. The PC software (eg, Microchip MPLAB or Atmel AVR Studio) is then used to program or reprogram the microcontroller.

Problems

This is great for project development, but you won't always have a complete circuit with a programming header when you need to program a micro.

It may be that the circuit operates at 230V AC mains and so you can't safely plug in a programmer. Or perhaps the circuit connects the micro's programming pins to other components which interfere with on-board programming.

Maybe there just isn't room for the programming header on the board because it wouldn't fit, or there is one, but you can't get to it once the board is mounted in its case. So, often it's just more convenient to pop the micro out and take it to a computer for programming.

Adaptor board

In short, there are lots of reasons why you might want to program a micro but an in-circuit programmer alone won't do the job. That's where the *PIC/AVR Programing Adaptor Board* comes in. It forms a circuit for the microcontroller to operate in, and provides the programming header connection and power supply. Once it's set up and the micro is locked into the ZIF socket, you fire up the serial programmer and program the chip as usual.

We used to wire up a socket on stripboard every time we wanted to program a new chip, but that is inconvenient. There are so many different pin configurations and power supply requirements that you end up with dozens of the things floating around. You also have to bend the IC pins to get it into a standard socket and then it can be difficult to pull out without mangling them.

Some programming adaptor boards available on the Internet use multiple ZIF sockets to suit different micros. Unfortunately, good ZIF sockets are quite expensive, so these boards usually use cheap ones, which don't last very long. And you'd need an awful lot of them to support a large portion of the PIC range.

Main features and supported microcontrollers

Features

- Runs off a 9V-to-12V DC plugpack or USB 5V power
- Programs most Microchip PICs and Atmel AVR microcontrollers in DIP
- Selectable 3.3V or 5V micro power supply
- Easy configuration – chip type selected with 8-way DIP switch
- Electronic fuse protects micro
- Uses high-quality, reliable 40-pin universal ZIF socket
- Compatible with PICkit 3 and AVRISP MkII

Supported microcontrollers

- Virtually all PIC12s, PIC16s and PIC18s
- Most PIC24s and dsPIC33s
- Most ATtiny and ATmega devices
- Over 450 different microcontrollers supported – see panel on page 26

Features

This programming board supports over 400 different 8-bit and 16-bit PICs – around 90% of the currently available range. It also supports about 45 different Atmel microcontrollers, covering most of the popular ATtiny and ATmega micros. It is capable of programming the vast majority of microcontrollers used in *EPE* projects in the last 10 years or so.

The programming adaptor board has its own power supply, since not all ICSP units can supply power to the micro. It also has soft-power control with over-current/short-circuit protection, to prevent damage to the micro in case something goes wrong.

The on-board power supply can provide 3.3V or 5V, depending on what the micro to be programmed needs. In addition, the micro is always inserted into the ZIF socket with pin 1 at upper left, making it easy to use.

Design

Before drawing up the circuit, we surveyed the entire range of 8-bit and 16-bit PICs and AVRs to figure out what proportion of the range we could support. There are nearly 500 different PICs in DIP packages, with about 30 different pin configurations. The AVR range is smaller, with less than 100 parts and eight different pinouts.

Supporting them all is a huge ask, but we figured that with 17 different pin configurations (13 for PICs and four for AVRs) we could cover about 90%, including all the most popular micros ranging from 8-pin up to 40-pin DIP parts.

We have to connect different pins to V_{CC} and ground, depending on which micro is inserted. We also need to route the programming signals and voltages to the appropriate pins. For AVRs, it's also useful to be able to drive the clock pins with a square wave during programming, as they don't automatically switch to the internal oscillator in programming mode (unlike PICs).

Having sorted out what was required, the next question was how to achieve it. Essentially, what we need is a type of sparse crossbar or matrix switch – think of a telephone exchange.

We have a 40-pin socket, two power supplies rails (0V and 3.3V/5V), three or four programming signals/voltages and a couple of clock signals (we'll explain that later). We need to connect some combination of these for a given micro, and ideally this should not involve a lot of effort for the user.

There are three obvious ways to do it: using jumper shunts, relays or electronic switches. We ruled out the relay option almost immediately; we would need at least 50 relays and it would have been a huge PCB.

Jumper shunts would be a cheap and cheerful solution, but then you, the user, would have to spend time reconfiguring the board one pin at a time, based on a whole series of diagrams. That would be a recipe for a disaster and besides, technology is supposed to make your life easier!

So we decided on electronic switching using MOSFETs. They are quite small and cheap and can easily be controlled by digital logic, making configuration a snap.

Circuit description

The resulting circuit is quite complicated, due to the large number of different configurations and how many pins need to be connected for each. So we have broken it up into sections, with Fig.1 showing the power supply switching and Fig.2 showing the control logic and serial data multiplexing. First, let's examine IC1 to IC3 in Fig.2.

We are switching the serial programming signals using CMOS 1-to-8 analogue multiplexer ICs (4051B). There are two such signals for PICs (PGD and PGC) and three for Atmel AVRs (MOSI, MISO and SCK). To simplify the circuit, we join PGD with MOSI and PGC with SCK; only one set is used at a time. These three programming lines are connected to the 'Z' terminals on the ICs.

The active-low enable pins of these three ICs ($\overline{\text{EN}}$) are joined together. When they are pulled low, the 'Z' terminals are connected to one of the 'Y' terminals. Which one depends on the state of input pins A0 to A2. If A0 to A2 are all low for one IC, its 'Z' is connected to 'Y0'. If S0 is high and the rest are low, giving a binary input of 1, 'Z' is connected to 'Y1' and so on.

We have specified HEF4051Bs, which are pin-compatible with the original 4051Bs, but have half the on-resistance between connected terminals (40Ω).This is important for reasons that will be explained later.

The first three DIP switches in S1, labelled DIP0 to DIP2, drive the A0 to A2 inputs of these three ICs. The Y0 to Y7 terminals of each are connected so that for each combination of DIP0 to DIP2, one of the programming headers is connected to the appropriate pins for one type of micro. $\overline{EN}$ is driven low simultaneously with the micro power supply being switched on, so that when the micro has no power, the programmer is disconnected.

IC1 to IC3 run from 16V, slightly higher than the normally specified 15V, but below the 18V maximum. They can, therefore, not only pass the 3.3V or 5V digital signals, but also withstand the 13.5V which can be applied to the MCLR/V_{PP} pin when programming a PIC. In some cases, pin 1 is connected to V_{PP} and this pin is also connected to IC1, so it must be able to withstand this voltage.

Each programming pin connected to IC1 to IC3 is also wired to a dual Schottky diode, which is connected between the supply rails (D6 to D8). These prevent the programmer (connected via CON1 or CON2) from driving the terminals of IC1 to IC3 beyond their supply rails when the adaptor board power supply is switched off.

Programming voltage

The 13.5V mentioned earlier comes from the V_{PP} pin of CON1, the ICSP header for PICs. This is used to power the micro's internal flash programming circuit.

Because the PIC draws some current from this rail during programming, we can't use another HEF4051BT to route it, since the 40Ω series resistance would be an issue. Instead, we use discrete analogue switches comprising surface-mount dual MOSFETs Q18 to Q21 – see upper left of Fig.1.

Each pair is connected drain-to-drain. One of the source terminals is connected to V_{PP} on the programming socket, while the other is connected to one of pins 1, 4, 9 or 10 on the ZIF socket. The gates (G) are tied together.

When the gates are held at 0V, both MOSFETs are off, since the source voltages are never below ground (0V). The body diodes are connected cathode-to-cathode, so at least one is reverse biased and no current can flow through them either.

When the gates are pulled up together to +16V, the gate-source voltages will be in the range of 2.5V to 16V, depending on the source voltages. These are in the range of 0V to 13.5V. Even with just 2.5V between gate and source, the FDS6912A MOSFETs switch on, applying V_{PP} to the connected pin. If the programmer pulls V_{PP} low, the micro pin will also go low as the analogue switch allows current to flow in either direction.

Atmels

When programming Atmel AVR microcontrollers, the reset pin is also used, but the programmer only needs to pull it low to enable the micro's programming mode. We have provided a reset pushbutton (S4 in Fig.2), which also pulls this line to ground. Sometimes, when a micro is already running code, you need to do this before you initiate programming.

There is a further difference with Atmel chips. If they have been configured to run from a crystal, ceramic resonator or external clock, they expect this to be present during programming as well as normal operation. This is in contrast to PICs, which automatically switch to their internal oscillator when programming mode is enabled.

So that you can still program chips set up in this way (and many will be), the adaptor board can supply a clock signal to the micro. This works even if it is expecting an external crystal; as long as it gets a square wave on both clock pins it will operate.

This facility is provided by IC4 and IC5, which are also 4051Bs. When they are enabled, they apply the 1MHz square waves CLK and $\overline{CLK}$ to the XTAL1 (clock input) and XTAL2 (clock output) pins of the micro. They are automatically disabled while programming PICs; $\overline{CLKENA}$ and hence their $\overline{EN}$ inputs are kept high.

Switching power

We also need to supply power to the micro. Some micros have a single pair of power supply pins (V_{CC} and GND) while others have multiples of each. These pins must have a low source impedance at high frequencies (1MHz+) or the micro will not operate correctly.

Normally, this is achieved by connecting power supply bypass capacitors between each pair of supply pins. But we can't put capacitors directly between ZIF socket pins because while they may be used to supply power for one type of micro, another may use the same pins for serial programming. Large value capacitors would just shunt the programming signals to ground.

Instead, we have connected multiple low-ESR bypass capacitors between the V_{CCS} (micro power supply) and GND rails around the ZIF socket. We then switch those rails directly to the appropriate socket pins using low on-resistance MOSFETs. The static on-resistance for the FDS6912As is about 0.02Ω, and this is effectively in series with the bypass capacitor ESRs, for both V_{CC} and GND pins. The total supply impedance is therefore quite low (<0.1Ω).

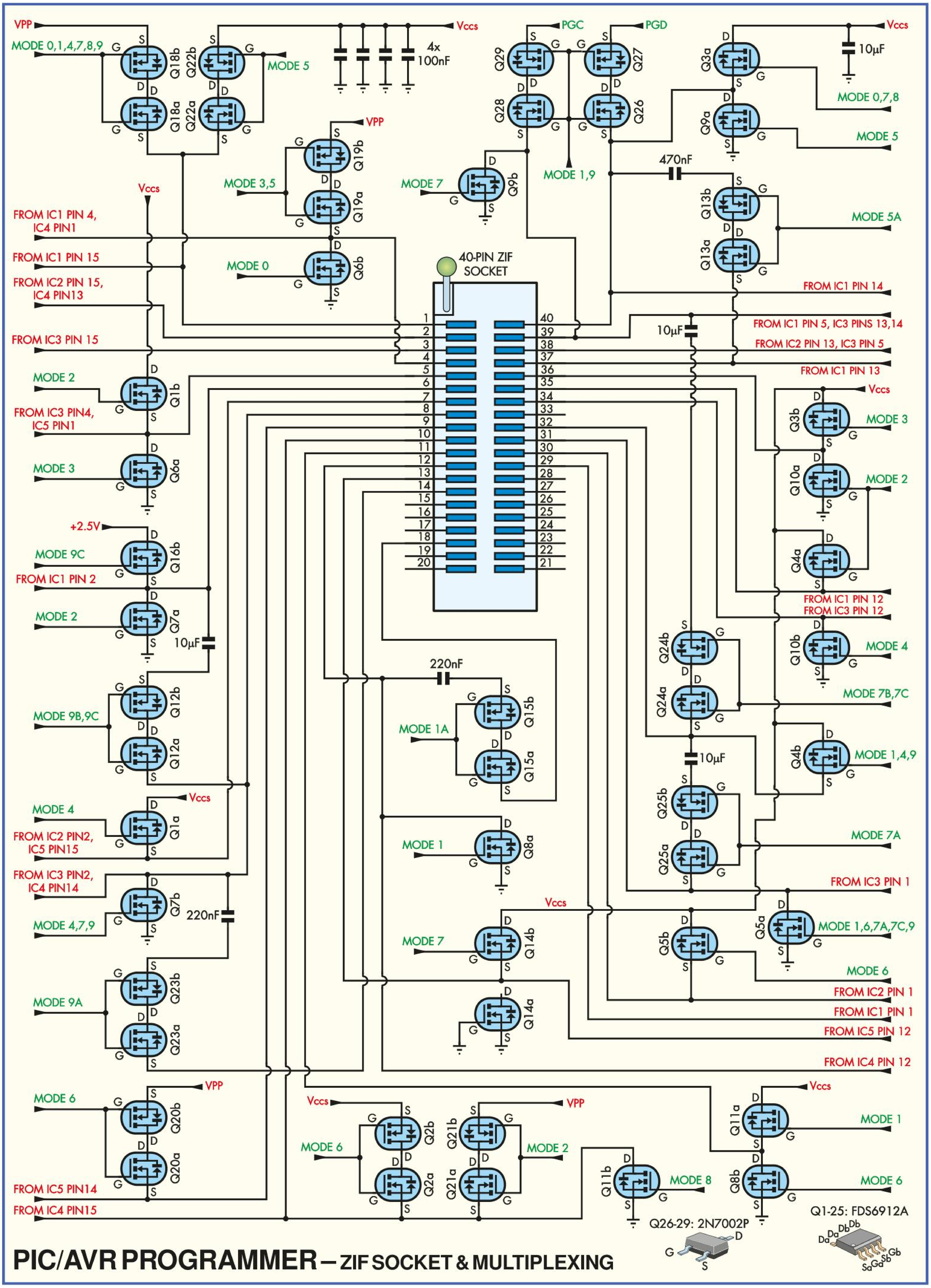
Fig.1: the ZIF socket and power supply switching (multiplexing) section of the programmer. The micro is placed in the 40-pin ZIF socket and MOSFETs Q1a/b to Q25a/b connect the various pins to V_{CC}, GND and MCLR/V_{PP} as required. Some MOSFETs also connect capacitors between pairs of pins as necessary. In addition, MOSFETs Q26 to Q29 connect serial programming lines PGC and PGD to pins 39 and 40 respectively, for high-speed programming of certain PICs.

In most cases, a single MOSFET switches power to one of the micro pins. For example, Q10a (right side) connects pin 36 to ground for MODE 2, while Q3b connects the same pin to V_{CCS} in MODE 3. In both cases, the gate is pulled to +16V to turn the MOSFET on and to 0V to turn it off.

However, for pins which share V_{PP} (~13.5V) and V_{CCS} (3.3V/5V), two MOSFETs are connected drain-to-drain for V_{CCS}, just as they are to supply V_{PP}. For example, Q22a and Q22b (upper left) connect pin 1 to V_{CCS}. This is necessary to prevent the higher V_{PP} voltage from feeding back into V_{CCS} when it is turned on.

In total, there are 13 MOSFETs connecting various pins to V_{CCS} and 12 for GND. Then there are an additional six dual MOSFETs (ie, a total of 12) which connect various capacitors between pins as required for some micros. These latter FETs are all configured as analogue switches, in series with the capacitors. For example, Q12 (left side) connects a 10µF capacitor between pins 6 and 8, to filter the core supply voltage of certain micros (dsPIC33s and PIC24s).

Q16b supplies 2.5V to pin 6 if required. Q14a is unused and has its gate and source tied to ground. Three additional MOSFETs are used in the power supply, to be described later. In total, there are 25 FDS6912A dual MOSFETs surrounding the ZIF socket. This may seem like a lot, but they are relatively cheap.


VPP
MODE 0,1,4,7,8,9
Q18b
Q18a
Q22b
Q22a
MODE 5
Vccs
4x
100nF
PGC
PGD
Q29
Q28
Q27
Q26
Q3a
Q9a
10µF
MODE 0,7,8
MODE 5
MODE 1,9
470nF
Q13b
Q13a
MODE 5A
VPP
Q19b
Q19a
MODE 3,5
MODE 7
Q9b
MODE 0
Q6b
Vccs
FROM IC1 PIN 4,
IC4 PIN1
FROM IC1 PIN 15
FROM IC2 PIN 15,
IC4 PIN13
FROM IC3 PIN 15
40-PIN ZIF
SOCKET
FROM IC1 PIN 14
FROM IC1 PIN 5, IC3 PINS 13,14
FROM IC2 PIN 13, IC3 PIN 5
FROM IC1 PIN 13
10µF
MODE 2
Q1b
FROM IC3 PIN4,
IC5 PIN1
MODE 3
Q6a
Vccs
Q3b
MODE 3
Q10a
MODE 2
Q4a
+2.5V
MODE 9C
Q16b
FROM IC1 PIN 2
MODE 2
Q7a
10µF
FROM IC1 PIN 12
FROM IC3 PIN 12
Q10b
MODE 4
Q24b
Q24a
MODE 7B,7C
220nF
MODE 9B,9C
Q12b
Q12a
MODE 1A
Q15b
Q15a
10µF
Q4b
MODE 1,4,9
Q25b
Q25a
MODE 7A
MODE 4
Q1a
Vccs
FROM IC2 PIN2,
IC5 PIN15
MODE 1
Q8a
FROM IC3 PIN 1
FROM IC3 PIN2,
IC4 PIN14
Q7b
MODE 4,7,9
220nF
Vccs
MODE 7
Q14b
Q5b
Q5a
MODE 1,6,7A,7C,9
MODE 6
FROM IC2 PIN 1
FROM IC1 PIN 1
FROM IC5 PIN 12
MODE 9A
Q23b
Q23a
Q14a
FROM IC4 PIN 12
MODE 6
Q20b
Q20a
VPP
Vccs
VPP
Vccs
MODE 6
Q2b
Q2a
Q21b
Q21a
MODE 2
Q11a
MODE 1
Q11b
MODE 8
Q8b
MODE 6
FROM IC5 PIN14
FROM IC4 PIN15
Q26-29: 2N7002P
Q1-25: FDS6912A
G
D
S
Da
Db
Sa
Ga
Sb
Gb
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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40

PIC/AVR PROGRAMMER – ZIF SOCKET & MULTIPLEXING

]

Supported microcontrollers

[x = any digit, (A) = with or without A suffix]

Microchip

PIC12F, PIC12HV: All [25]
PIC16F, PIC16LF, PIC16HV: All but PIC16F57 and PIC16F59 [149]
PIC18L, PIC18LF: All* [132]
PIC24E: All [8]
PIC24F: All but PIC24F04KA20x, PIC24F04KLx00 and PIC24FJ16MC101 [29]**
PIC24H: All but PIC24HJ12GP20x [14]
dsPIC33E: All [12]
dsPIC33F: All but dsPIC33FJxxGSxxx and those ending with -101 [26]

*** PIC18F2331, PIC18F44J10 and PIC18F45J10 require an extra component in the ZIF socket.**
**** PIC24FxxKA30x (12 types) require an extra component in the ZIF socket.**

Atmel

ATtiny13(A)(V), ATtiny15L, Attiny25/45/85(V) [10]
ATtiny261/461/861(A)(V) , Attiny26(L) [11]
ATtiny2313(A)(V), Attiny4313 [4]
ATtiny48/88, Atmega48/88/168/328(P)(A)(V), Atmega8(A)(L) [21]
ATmega16/32(A)(L), Atmega164/324/644/1284(P)(A)(V) [20]
ATmega8535(L) [2]

Total: 463 fully supported, 15 programmable with additional components. Note: some parts no longer in production have not been checked but are likely to work.

Parasitic capacitance

The problem with all these MOSFETs is that even when switched off, they are effectively still present in the circuit. While the drain-source leakage current is very low and can be ignored, the output capacitance is an issue. This refers to the capacitance seen at the drain pin, which is the sum of the drain-source and drain-gate capacitances.

This capacitance is highest (about 1nF) when the MOSFET's drain-source voltage is zero. As the drain-source voltage increases, it drops to about 150pF. With multiple MOSFETs on a single pin, this can add up, and in combination with the 40Ω resistance of the analogue multiplexer ICs, IC1 to IC5, it forms low-pass filters for the serial programming and clock signals. This limits the signals passed to a maximum of about 1.5MHz.

In most cases, this is not a problem. We tested the programming adaptor board with a variety of PIC and AVR chips (about 20 different types), using the PICkit 3 and AVRISP MkII serial programmers. We found the programming speed was typically around 0.5MHz and it worked reliably in each mode.

There is one situation where the parasitic capacitance is an issue, and this is when programming PIC18FJ devices. The PICkit 3 uses a higher clock frequency for these, of about 2MHz. It is, therefore, necessary to have four small additional MOSFETs, Q26 to Q29. They form analogue switches in parallel with IC1 and IC3, for routing the PGD and PGC signals to pin 40 and pin 39 respectively.

For PIC18FJs then, the series resistance to the programming signals drops to a couple of ohms, allowing the higher frequency signals to pass.

These four additional MOSFETs are 2N7002Ps. The 2N7002 is a surface-mount version of the 2N7000. The P suffix is important, as it indicates a lower on-resistance (1Ω compared to 2.5Ω) which is required for reliable programming of PIC18FJs.

Control logic

All this switching is controlled by the circuitry shown in Fig.2. To program a particular micro, eight DIP switches (S1) are set to the appropriate positions. Each DIP switch is connected to a pull-down resistor, so if the DIP switch is off, the corresponding line labelled DIP0 to DIP7 is 0V and if the switch is on, the line is at 16V.

DIP0 to DIP3 configure the analogue multiplexers IC1 to IC5, described earlier, They are also connected to the four inputs (A0 to A3) of CMOS 4028B BCD-to-decimal decoder IC6. Depending on the positions of DIP0-DIP3, one of its 10 outputs (O0 to O9) is high and the rest are low. These outputs then drive the gates of some of the MOSFETs shown in Fig.1, turning the appropriate ones on for that mode.

For example, in MODE 5, output O5 of IC6 goes high and turns on MOSFET Q9a, which connects pin 40 of the ZIF socket to ground. Some MOSFETs must be turned on in more than one mode, and so the 10 mode lines are also fed into nine OR gates: IC7a to IC7c, IC8a to IC8c and IC9a to IC9c.

In some cases, these are cascaded. So when MODE 1, 4 or 9 is selected, the output of IC9b (MODE 1,4,9) is high and this turns on MOSFET Q4b, supplying 3.3V or 5V to pin 32 of the micro.

But the scheme described above only gives us 10 possible pin configurations and as we said earlier, we need 17. The additional seven configurations use the same power and programming pins as the other 10, but involve different combinations of capacitors connected between other pins and, in one case, an additional 2.5V supply.

Extra control signals

The extra control signals are derived from the 10 mode signals and the positions of two more DIP switches, DIP4 and DIP5. This is achieved using eight 2-input AND gates, IC10a to IC10d and IC11a to IC11d, in combination with inverter gates IC12a to IC12c and 2-input OR gate IC7d. The additional modes are labelled A, B and C and are selected by switching DIP4 on (mode A), DIP 5 on (mode B) or both on (mode C).

If MODE 9 is selected and both DIP4 and DIP5 are on (high), the output of AND gate IC10a (MODE 9B,9C) is high, as is the output of AND gate IC10c (MODE 9A,9C). As a result, the output of IC10b (MODE 9C) is also high.

With MODE 9B,9C and MODE 9C both high, MOSFETs Q12a and Q12b connect a 10µF capacitor between pin 8 and pin 6 while at the same time, Q16b turns on, supplying 2.5V to pin 6. This suits PIC18LF2xJ5x microcontrollers.

Inverter stages IC12e and IC12f are unused, so their inputs are tied to +16V to prevent oscillation. Two-input OR

Parts List – PIC/AVR Programming Adaptor Board

- 1 PCB, code 899, available from the *EPE PCB Service*, size, 116mm × 127mm
- 1 40-pin Universal ZIF socket, 0.6-inch-wide pin spacing
- 1 40-pin production DIL socket, 0.6-inch-wide pin spacing
- 1 220µH bobbin inductor (Jaycar LF1104 (or similar) (L1)
- 1 1MHz or 1.008MHz crystal or 2-pin ceramic resonator (X1)
- 1 100kΩ 9-pin 8-resistor network
- 1 6-way pin header strip (CON1)
- 2 10-way shrouded vertical IDC socket (CON2)
- 1 PCB-mount USB type B socket (CON3)
- 1 PCB-mount DC socket (CON4)
- 1 2-way polarised header, 2.54mm pitch (CON5)
- 1 3-way pin header strip and shorting block (LK2)
- 1 8-way DIP switch (S1)
- 3 PCB-mount tactile pushbuttons (S2 to S4)
- 1 miniature PCB-mount SPDT slide switch (S5)
- 5 M3 × 6mm machine screws
- 1 M3 shakeproof washer
- 1 M3 nut
- 4 M3 × 12mm tapped nylon spacers

Semiconductors

- 5 HEF4051BT 8-way analogue multiplexers [SOIC-16] (IC1to IC5)
- 2 CD4028BM BCD-to-decimal decoders [SOIC-16] (IC6, IC17)
- 2 HEF4071BT quad 2-input OR gates [SOIC-14] (IC7, IC8)
- 1 CD4075BM triple 3-input OR gate [SOIC-14] (IC9)
- 2 HEF4081BT quad 2-input AND gates [SOIC-14] (IC10, IC11)
- 1 HEF4069UBT hex inverter [SOIC-14] (IC12)
- 1 SN74HC04D hex inverter [SOIC-14] (IC13)
- 1 HCF4013BM1 dual D-type flip-flop [SOIC-14] (IC14)
- 1 OP07CD precision op amp [SOIC-8] (IC15)
- 1 LM293D dual low-power comparator [SOIC-8] (IC16)
- 1 7805T 5V 1A linear regulator (REG1)
- 1 AP1117E33 3.3V low-dropout linear regulator [SOT-223] (REG2)
- 1 SPX1117M3-L-2-5 2.5V low-dropout linear regulator [SOT-223] (REG3)
- 1 MC34063ADG switchmode controller [SOIC-8] (REG4)
- 25 FDS6912A dual independent *N*-channel MOSFETs [SOIC-8] (Q1 to Q25)
- 4 2N7002P *N*-channel MOSFETs [SOT-23] (Q26 to Q29)

Diodes and LEDs

- 1 1N5819 1A Schottky diode (D1)
- 3 1N4148 small diodes (D2-D4)
- 1 1N4004 1A diode (D5)
- 3 BAT54S dual series Schottky diodes [SOT-23] (D6 to D8; Element14 1467519)
- 1 Green 3mm LED (LED1)
- 1 Yellow 3mm LED (LED2)
- 1 Red 3mm LED (LED3)

Capacitors

- 4 100µF 16V electrolytic
- 2 47µF 25V electrolytic
- 1 10µF 16V electrolytic
- 4 10µF 6.3V SMD X5R ceramic [3216/1206]
- 1 470nF MKT
- 2 220nF 50V SMD X7R ceramic [3216/1206]
- 11 100nF 50V SMD X7R ceramic [3216/1206]
- 14 100nF MKT
- 1 470pF disc ceramic
- 2 33pF disc ceramic

Resistors (1%, 0.25W)

- 1 1MΩ
- 1 100kΩ
- 1 68kΩ
- 5 47kΩ
- 1 13kΩ
- 1 4.7kΩ
- 3 2.2kΩ
- 1 1.1kΩ
- 2 1kΩ
- 1 220Ω
- 1 1Ω (1% or 5%)
- 1 0.1Ω SMD [3216/1206]

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gate IC8d is also unused and connected similarly.

Clock generator

Fig.2 also shows the crystal oscillator circuit which is based on hex inverter IC13, a 74HC04D. IC13a forms the oscillator in combination with crystal X1, two 33pF load capacitors, a 1MΩ biasing resistor and a 4.7kΩ current-limiting resistor. The 1MHz clock signal is then buffered by IC13b and IC13f, which are paralleled for increased drive strength. This signal then passes to IC5, to be connected to the micro's XTAL1 (clock input) pin, when enabled.

This clock signal is inverted again, by IC13c to IC13e (also paralleled) and this signal passes to IC4, which routes it to the micro's XTAL2 (clock output) pin, if enabled.

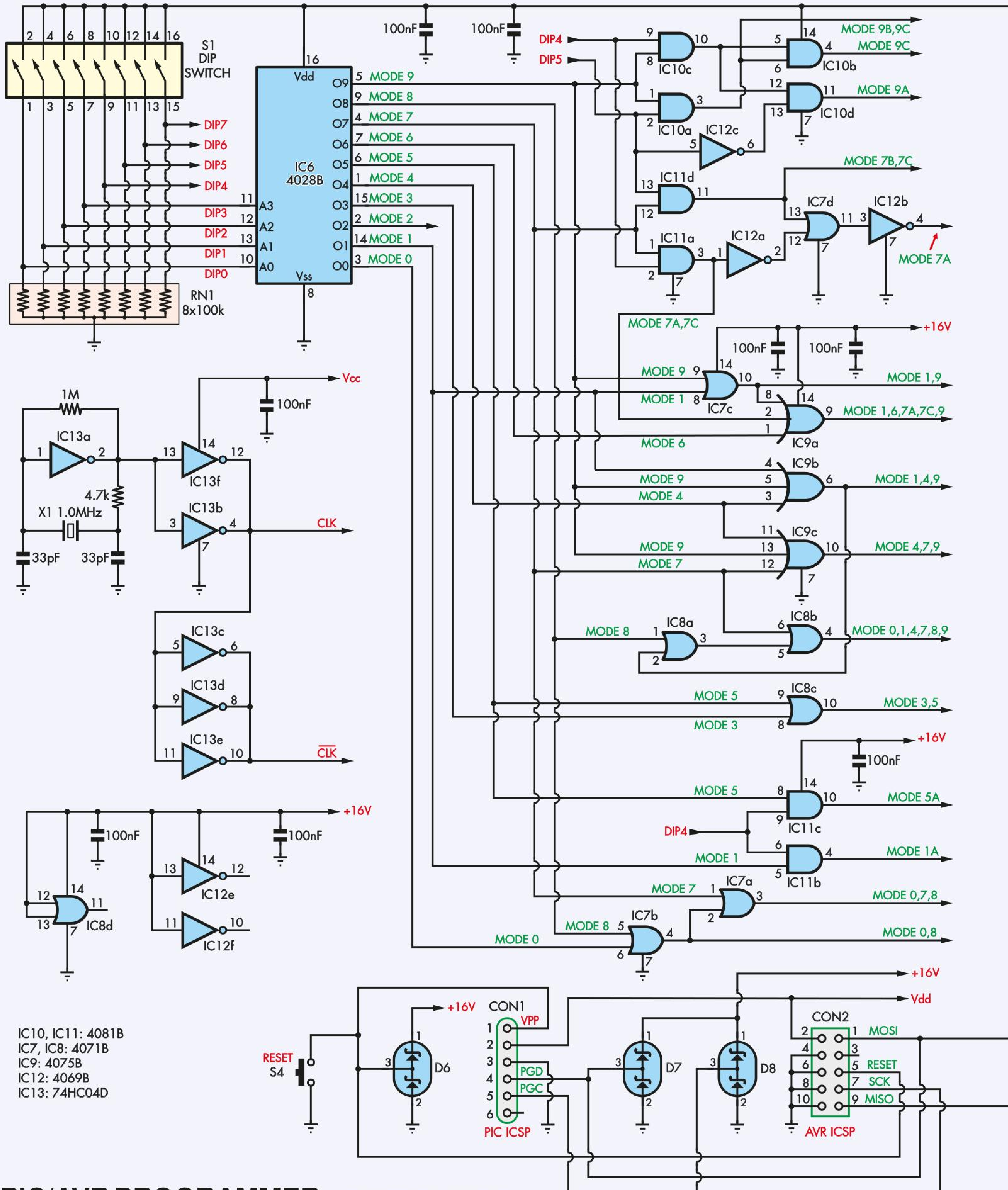
Both inverters must charge and discharge the parasitic capacitance at the target pin at 1MHz. This could be a couple of nanofarads. Their load impedance can be up to $40\Omega + (1 \div (2\pi \times 1\text{MHz} \times 2\text{nF})) = 120\Omega$, hence the use of multiple inverters in parallel.

Unfortunately, 1MHz crystals are not as common as 2MHz crystals. The circuit will work with a 2MHz crystal, but the dissipation in IC4 and IC5 increases due to the increased current required to drive the load capacitance at the higher frequency. We did not experience any failures in our prototypes, but cannot vouch for the long-term reliability of the circuit if using such a crystal.

If you do use a 2MHz crystal, avoid leaving the clock and micro power enabled for long periods, when programming at 5V. This is not an issue when programming PICs.

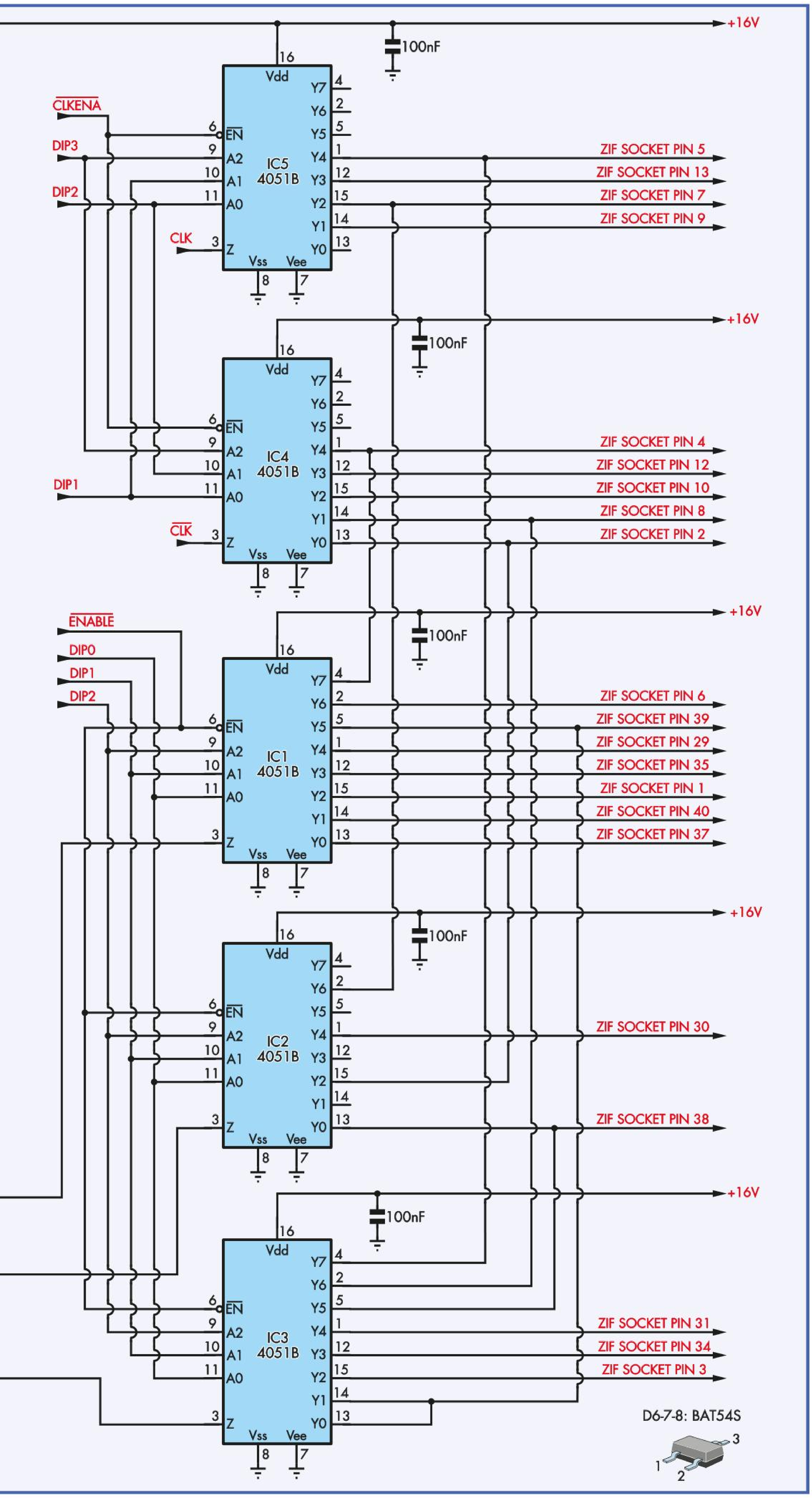
Power supply

Refer now to Fig.3 which shows the power supply. The unit can run from either a 9V-to-12V DC plugpack or a USB port. The plugpack is connected to CON4 and this disconnects the USB ground pin so that power can't flow back into the USB port. Diode D5 provides reverse polarity protection, and


S1
DIP
SWITCH
2 4 6 8 10 12 14 16
1 3 5 7 9 11 13 15
DIP7
DIP6
DIP5
DIP4
DIP3
DIP2
DIP1
DIP0
RN1
8x100k
IC6
4028B
Vdd
Vss
16
8
A3
A2
A1
A0
O9
O8
O7
O6
O5
O4
O3
O2
O1
O0
5 MODE 9
9 MODE 8
4 MODE 7
7 MODE 6
6 MODE 5
1 MODE 4
15 MODE 3
2 MODE 2
14 MODE 1
3 MODE 0
100nF
100nF
DIP4
DIP5
IC10c
IC10a
IC10b
IC10d
IC12c
IC11d
IC11a
IC12a
IC7d
IC12b
MODE 9B,9C
MODE 9C
MODE 9A
MODE 7B,7C
MODE 7A
MODE 7A,7C
+16V
100nF
100nF
MODE 9
MODE 1
IC7c
MODE 1,9
MODE 1,6,7A,7C,9
MODE 6
IC9a
IC9b
MODE 9
MODE 4
MODE 1,4,9
IC9c
MODE 9
MODE 7
MODE 4,7,9
MODE 8
IC8a
IC8b
MODE 0,1,4,7,8,9
MODE 5
MODE 3
IC8c
MODE 3,5
+16V
100nF
MODE 5
DIP4
IC11c
MODE 5A
MODE 1
IC11b
MODE 1A
MODE 7
IC7a
MODE 0,7,8
MODE 8
IC7b
MODE 0
MODE 0,8
Vcc
100nF
1M
IC13a
IC13f
IC13b
4.7k
X1 1.0MHz
33pF
33pF
CLK
IC13c
IC13d
IC13e
CLK
+16V
100nF
100nF
IC8d
IC12e
IC12f
IC10, IC11: 4081B
IC7, IC8: 4071B
IC9: 4075B
IC12: 4069B
IC13: 74HC04D
RESET
S4
D6
+16V
CON1
VPP
PGD
PGC
PIC ICSP
D7
D8
+16V
Vdd
CON2
MOSI
RESET
SCK
MISO
AVR ICSP

PIC/AVR PROGRAMMER – CONTROL LOGIC

Fig.2: the control logic for the adaptor board is shown at left, while IC1-IC5 (HEF4051Bs) connect the serial programming and clock lines to various pins on the ZIF socket (see Fig.1). 8-way DIP switch S1 selects the micro to be programmed and the switch states are decoded using the various logic ICs, to drive the appropriate MOSFETs and analogue switches.


+16V
100nF
16
Vdd
IC5
4051B
CLKENA
DIP3
DIP2
CLK
6
9
10
11
3
EN
A2
A1
A0
Z
Vss
Vee
8
7
Y7
Y6
Y5
Y4
Y3
Y2
Y1
Y0
4
2
5
1
12
15
14
13
ZIF SOCKET PIN 5
ZIF SOCKET PIN 13
ZIF SOCKET PIN 7
ZIF SOCKET PIN 9
IC4
4051B
DIP1
CLK
ZIF SOCKET PIN 4
ZIF SOCKET PIN 12
ZIF SOCKET PIN 10
ZIF SOCKET PIN 8
ZIF SOCKET PIN 2
ENABLE
DIP0
DIP1
DIP2
IC1
4051B
ZIF SOCKET PIN 6
ZIF SOCKET PIN 39
ZIF SOCKET PIN 29
ZIF SOCKET PIN 35
ZIF SOCKET PIN 1
ZIF SOCKET PIN 40
ZIF SOCKET PIN 37
IC2
4051B
ZIF SOCKET PIN 30
ZIF SOCKET PIN 38
IC3
4051B
ZIF SOCKET PIN 31
ZIF SOCKET PIN 34
ZIF SOCKET PIN 3
D6-7-8: BAT54S
1
2
3

REG1 then drops the supply voltage to the required 5V. For USB, 5V is drawn straight from the socket.

Either way, slide switch S5 acts as the power switch and when on, green LED1 lights up. The 5V rail is reduced to 3.3V by REG2, a low-dropout (LDO) linear regulator. These 5V and 3.3V rails provide the two power options for the micro.

The 5V rail also powers REG4, an MC34063 switch-mode regulator. This switches current through inductor L1 (a 220μH choke) and in combination with Schottky diode D1, generates the +16V logic supply. This only needs to deliver a few milliamps since the logic is all static. The ratio of the 13kΩ and 1.1kΩ resistors sets the output voltage to 1.25 × (13kΩ ÷ 1.1kΩ + 1) = 16.02V.

Link LK1 allows the power supply to be tested before voltage is applied to the rest of the circuitry. This is shorted for normal operation.

Voltage selection

MOSFETs Q17a and Q17b switch the 3.3V and 5V rails to the micro respectively; only one can be on at a time. Q17a turns on when DIP6 is high, but Q17b is only indirectly controlled by DIP7. IC17, another 4028B BCD-to-decimal decoder, is between the two.

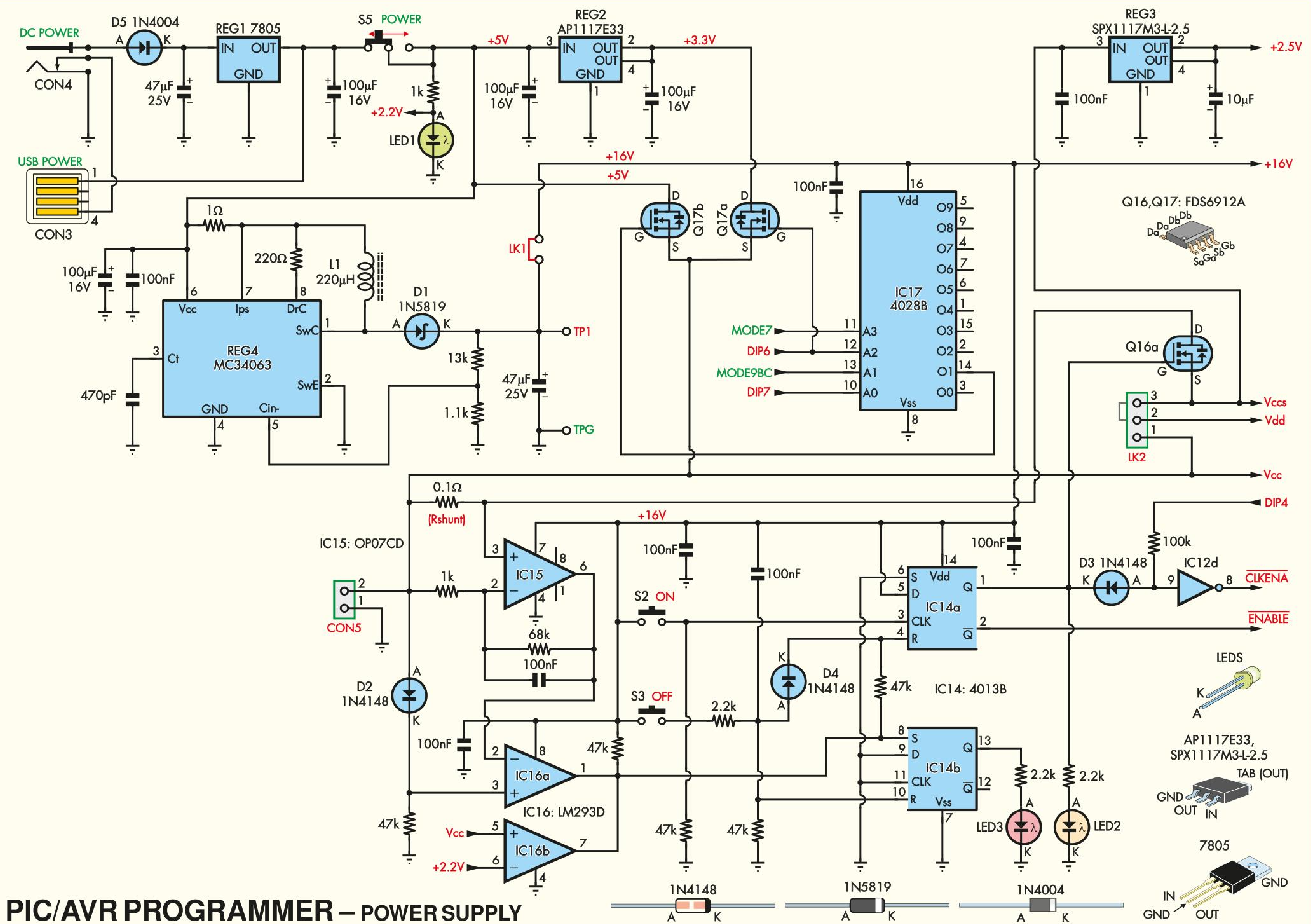
We don't want Q17b to turn on if Q17a is on, as this would short the 3.3V and 5V supplies together. Q17b is also disabled if the programmer has been set up for a micro, which will be damaged by 5V. So, for Q17b to come on, DIP6 must be off, DIP7 on and neither Mode 7 (for dsPIC33s) nor Modes 9B or 9C (for PIC24s) should be enabled.

Since Q17b's gate is connected to output O1 (pin 14) of IC17, it will only turn on if input A0 is high and inputs A1 to A3 are low, giving a binary input value of 1. This can only occur under the conditions specified above.

Electronic fuse

Whichever supply voltage is selected, current then flows from Q17a or Q17b through Rshunt (0.1Ω) and then through Q16a, to the micro's V_{CCS} (switched V_{CC}) supply. Q16a is the 'soft-power' switch, and this allows power to the micro to be cut quickly in an over-current condition.

This condition is detected by the voltage across Rshunt rising to a certain level. The voltage across it


DC POWER
CON4
D5 1N4004
A
K
REG1 7805
IN
OUT
GND
47µF 25V
USB POWER
CON3
1
4
S5 POWER
100µF 16V
1k
+2.2V
LED1
+5V
REG2 AP1117E33
100µF 16V
+3.3V
REG3 SPX1117M3-L-2.5
100nF
10µF
+2.5V
+16V
Q16,Q17: FDS6912A
1Ω
220Ω
L1 220µH
D1 1N5819
100µF 16V
100nF
REG4 MC34063
Vcc
Ips
DrC
SwC
Ct
SwE
GND
Cin-
470pF
13k
1.1k
47µF 25V
TP1
TPG
LK1
Q17b
Q17a
D
G
S
IC17 4028B
Vdd
Vss
A3
A2
A1
A0
O9
O8
O7
O6
O5
O4
O3
O2
O1
O0
MODE7
DIP6
MODE9BC
DIP7
Q16a
LK2
Vccs
Vdd
Vcc
DIP4
0.1Ω (Rshunt)
IC15: OP07CD
CON5
IC15
68k
100nF
D2 1N4148
IC16a
IC16b
IC16: LM293D
47k
S2 ON
S3 OFF
2.2k
D4 1N4148
IC14a
IC14b
IC14: 4013B
S
D
CLK
R
Q
Q̅
100k
D3 1N4148
IC12d
CLKENA
ENABLE
LED3
LED2
LEDS
AP1117E33, SPX1117M3-L-2.5
TAB (OUT)
GND
OUT
IN
7805
1N4148
1N5819
1N4004

PIC/AVR PROGRAMMER – POWER SUPPLY

Fig.3: the adaptor power supply. Power comes from a 9V-to-12V DC plugpack or a USB cable. From these, 16V, 5V, 3.3V and 2.5V rails are generated. 16V powers the logic, while the rest can supply the micro. IC14 controls power to the micro, with IC15 and IC16 monitoring the current flow. If the current limit is exceeded, IC14 turns the power off and turns on red LED3.

is amplified by precision op amp IC15 and monitored by comparator IC16a.

With 100mA through Rshunt, there is just 10mV across it. If IC16a monitored this directly, its maximum offset voltage of ±9mV would mean an error of up to ±90mA. That's clearly too much, given that we want a nominal current limit of around 100mA.

By comparison, IC15 has a very low maximum input offset voltage (0.15mV). It is configured for a gain of 69, ie, (68kΩ + 1kΩ) ÷ 1kΩ. This reduces the error due to IC16b's offset voltage to around ±1.5mA. A 100nF feedback capacitor provides a time delay (of about 1ms), so that very brief current transients do not trip the current limit.

This is necessary since when power is first applied, the charging of the supply bypass capacitors causes a brief current spike which could otherwise cause a nuisance trip.

IC15's output is relative to V_{CC} and is negative, ie, the more current that flows through Rshunt, the lower IC15's output voltage is. The reference voltage it is compared against must also be relative to V_{CC}, and this is generated with small-signal diode D2 and a 47kΩ load resistor. The voltage drop across the 1N4148 diode is quite predicable at around 0.6V.

In combination with IC15's gain, this sets the current limit to about 90mA (0.6V ÷ 69 ÷ 0.1Ω). If the micro draws any more than this during programming, IC16a's output goes high and the supply switches off. This was sufficient for programming all micros that we tested.

There is an additional consideration; when the micro supply is off, input pin 2 and pin 3 of op amp IC15 are outside its normal operating range (1V to 15V). Its output is, therefore, undefined and it could switch power off before V_{CC} rises to a normal level.

Comparator IC16b prevents this. It compares V_{CC} against the 2.5V rail and so its output remains low until V_{CC} rises above the 2.2V reference derived from LED1. Since the outputs of IC16a and IC16b are connected together, this prevents the over-current signal from being asserted until the supply voltage is high enough for IC15 to monitor the current through Rshunt.

Power control

IC14a is a flip-flop which drives the gate of Q16a and hence controls power to the micro. Its pin 4 reset input is driven by comparator IC16a, mentioned earlier. If excessive current flow is detected and IC16a's output goes high, the 47kΩ resistor pulls pin 4 of IC14a high and this resets IC14a, cutting power to the micro.

IC14a's 'set' input (pin 6) is tied to ground and its data input (pin 5) is pulled high. It is, therefore, switched on by a positive transition on clock input pin 3. The clock pin is driven by pushbutton S2 with an associated 47kΩ pull-down resistor, hence pressing S2 turns the micro power on.

Similarly, pushing S3 turns the power off, since this pulls the reset input (pin 4) high via a 2.2kΩ resistor and diode D4. IC14a is also reset initially by the 100nF capacitor from D4's anode to +16V, so micro power is off when the unit is first switched on.

IC14b, the other half of the dual flip-flop IC, is used to indicate if an over-current trip occurs. When the output of comparator IC16a goes high, it not only resets IC14a, but it also sets IC14b via pin 8. This turns on red LED3 to indicate a fault. This LED can then be turned off using pushbutton S3 (power off), since this pulls its pin 10 reset input high.

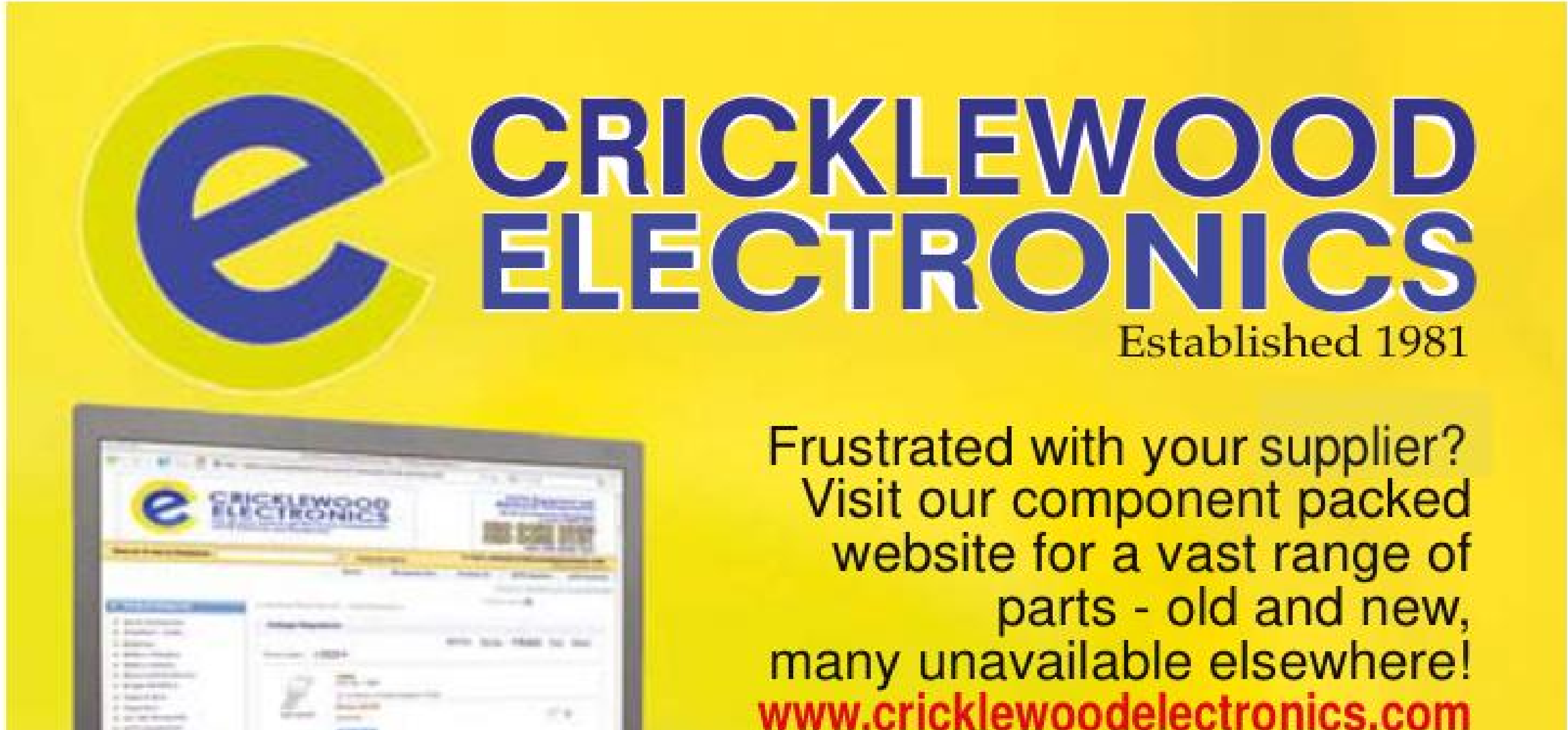
When the output of IC14a is high and MOSFET Q16a is on, supplying power to the micro, yellow LED2 is also lit. IC14a also drives the input of inverter stage IC12d, which enables clock signal multiplexers IC4 and IC5. DIP4 must also be on for the clock enable to be asserted, otherwise, pin 6 of IC12d remains low.

Pin header CON5 can be used to monitor V_{CC} externally, and if necessary, provide an off-board micro power supply. Three-pin header LK2 selects whether the ICSP receives power at the same time as the micro, or when the programming adaptor board is switched on. It is usually left in the position shown, with pin 2 and pin 3 shorted, selecting the former condition.

LDO regulator REG3 derives 2.5V from V_{CCS} (3.3V or 5V) when Q16a is on. This is required when programming PIC18LF2xJ5x micros.

More to come

Next month, we will provide the PCB overlay diagrams and the construction details. We'll also detail the set up and describe how to use the *Programming Adaptor Board*.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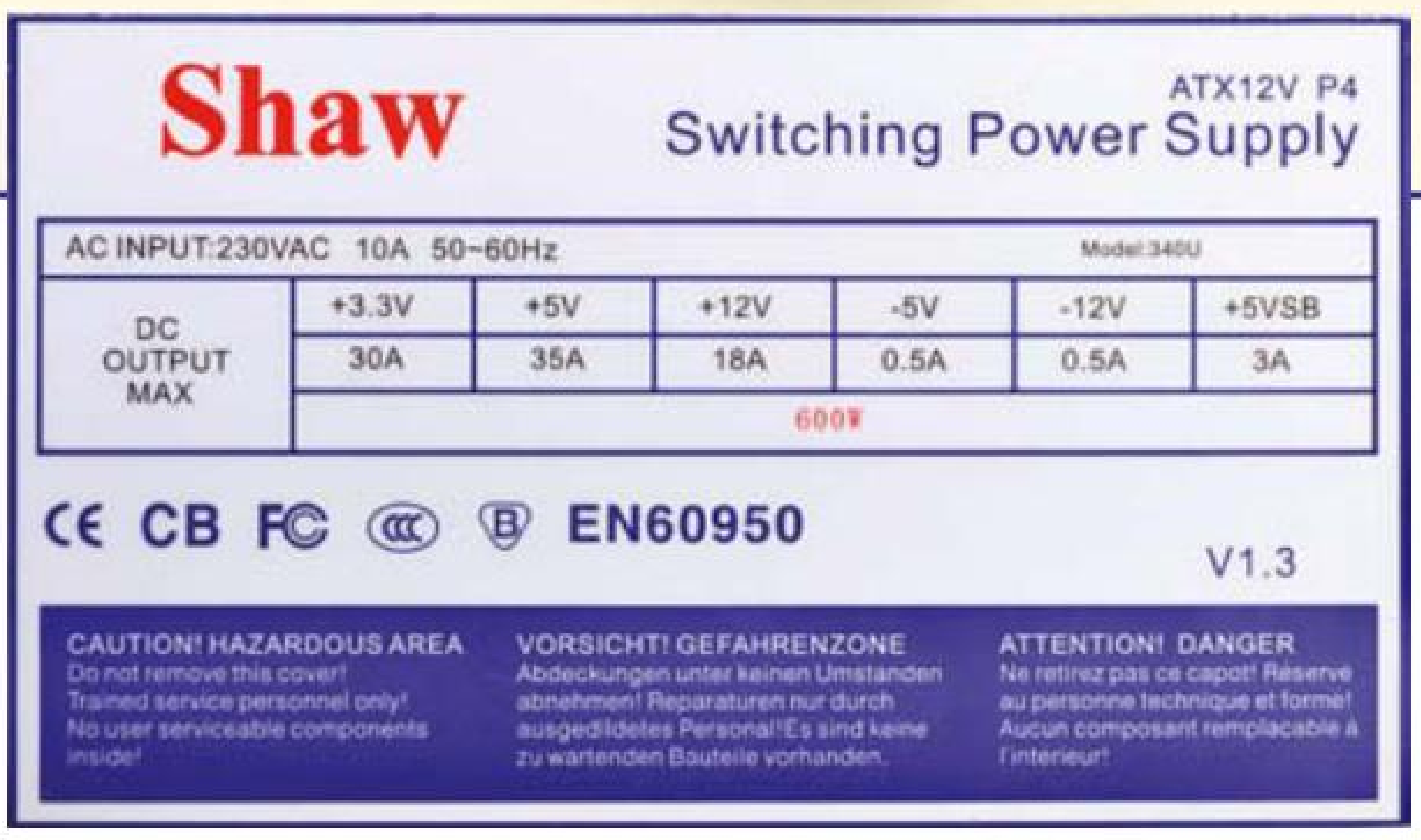
Your old PC may be past it... but its power supply might not be!

Cheap, High-Current Bench Supply

by Nicholas Vinen

If you've ever had to buy a high-current bench supply, you'll know they don't come cheap. But you may well have such a supply sitting unloved and (until now!) unwanted in the back of a cupboard. It's the power supply in that old computer you never quite got around to throwing away!



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V1.3

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No user serviceable components inside!

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ATTENTION! DANGER
Ne retirez pas ce capot! Réserve au personne technique et formé! Aucun composant remplacable à l'interieur!

WE ARE big fans of reusing **and** recycling old electronics. We're loathe to throw away anything which is still operational, even if it's obsolete. Manufacturing these devices involves much effort, so just throwing them away when they still work is wasteful.

This means that, among other things, we have a number of computer power supplies lying around, gathering dust. Some of these are still inside old computers which are too slow to be useful, while others are left over from upgrades (where the old supply wasn't up to the task of powering a new motherboard or CPU). Others were rescued from machines that were recycled or thrown away elsewhere.

Even if you don't have a spare computer power supply, these days they are cheaper to buy than an equivalent bench supply. They don't have particularly good voltage regulation, either in terms of absolute output voltage or ripple, but they do have multiple voltage rails, in some cases capable of delivering upwards of 30A. If all you need is a high-current, fixed-voltage supply (12V, 5V and possibly 3.3V), using a computer supply is a cheap and efficient option.

Note that we are not modifying the supply to provide different output voltages than those already offered; we are just making it much easier to use the existing rails for a bench supply.

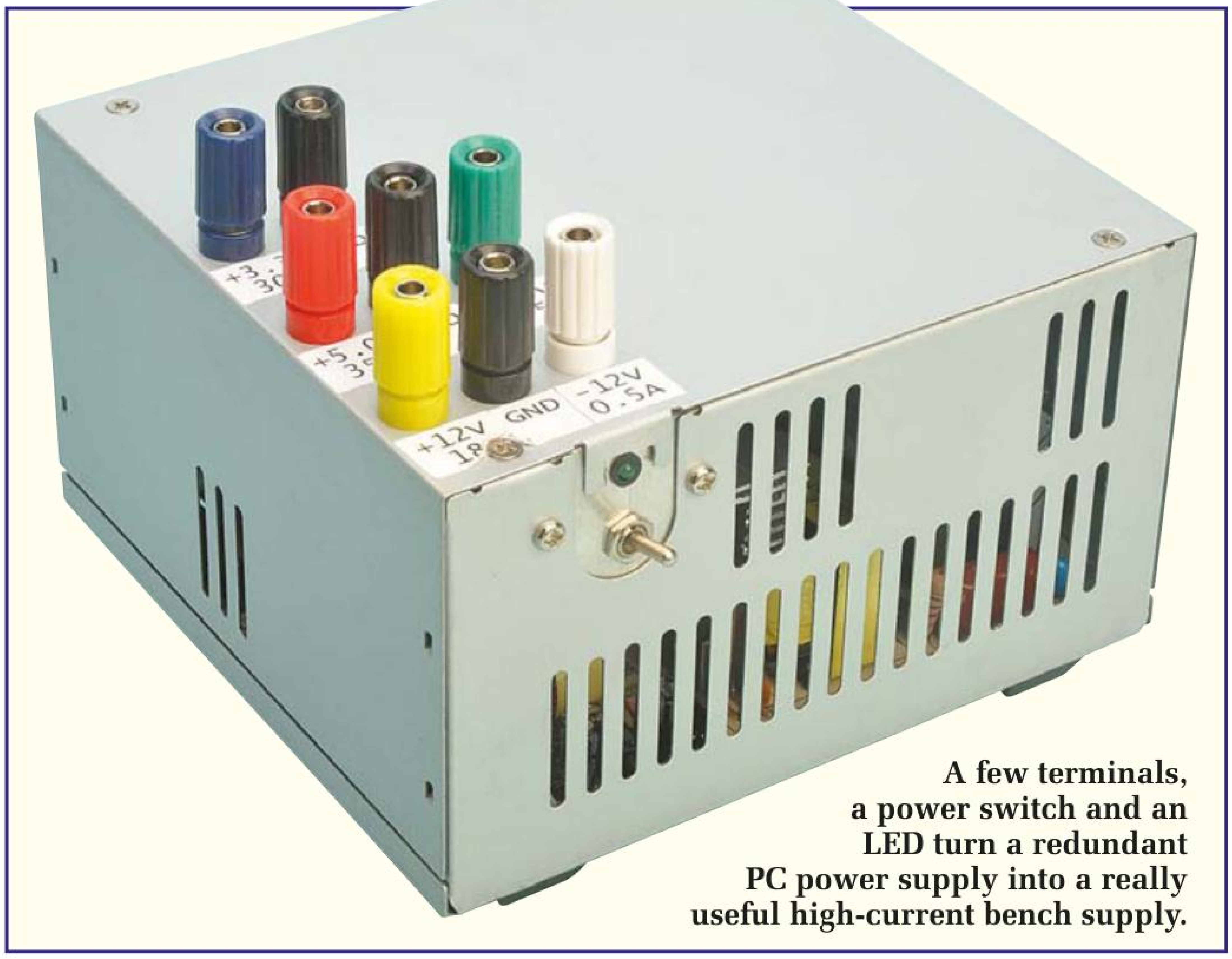
Choosing a supply

Our first task was to decide which supply to adapt. We have some of the old 'AT' supplies as well as the newer 'ATX' types. The latter are far more common these days and safer to work with since there is no external mains power switch. As ATX supplies are now pretty much universal (and also more powerful), that is what most constructors would use.

In the end, we chose a 600W Shaw brand supply. We decided against two others with higher current delivery because they are still useful for running a modern computer; and quiet and efficient to boot.

Of the rest, the Shaw delivers the most current at 12V (18A) as well as a healthy 35A at 5V and 30A at 3.3V. It also has both negative outputs (–5V and –12V; some supplies lack the –5V), rated at 0.5A each.

This particular supply was bundled with an ATX case, but it was noisy and inefficient at idle so we replaced it with a more expensive, but much



A few terminals, a power switch and an LED turn a redundant PC power supply into a really useful high-current bench supply.

DANGER!

THIS PROJECT IS NOT FOR BEGINNERS! ONLY TACKLE IT IF YOU KNOW WHAT YOU ARE DOING OR ARE PROPERLY SUPERVISED.

Internally, computer power supplies carry the full 230V AC mains voltage and must be seen as potentially lethal.

Much of the exposed internal circuitry and heatsinks float at the mains voltage.

NEVER open a computer power supply case or work on the supply with the IEC mains cable plugged in (turning it off is NOT good enough!).

Heed the warnings in the text!

better unit, leaving this one spare. In the role of a bench supply, these issues are quite minor, as it will only be operated intermittently.

Any ATX supply is suitable for conversion, but before you start, check the ratings, which are usually printed on a label attached to the side of the supply. Once you are happy that the current ratings are sufficient for your uses, you can begin the conversion, which should take no more than a few hours.

Parts

Which parts you need will vary slightly depending upon your supply and how many voltage rails you want to access.

YOU WILL NEED...

8 binding post terminals (three black, the rest different colours)
1 SPDT miniature toggle switch
1 3mm LED
1 3mm LED bezel
1 390Ω 0.25W resistor
4 stick-on rubber feet
2 M3 × 10mm machine screws, nuts and shakeproof washers
Small piece of aluminium plate, ~35mm × 35mm
Short lengths of 2.5mm and 4mm diameter heatshrink tubing
Adhesive labels

IN ADDITION YOU WILL NEED THE FOLLOWING TOOLS...

Screwdriver
Side-cutters
Soldering iron
Wire stripper
Needle-nose pliers
Centre punch
Drill and drill bits (3mm to 8mm)

Construction

First, a word on safety. Computer power supplies can kill: they rectify the 230V AC mains without the benefit of an isolation transformer and many sections of the circuitry are at full mains potential.

NEVER operate the supply with the lid open and always wait at least five minutes after switching off before opening it up again.

There are capacitors in the switch-mode supply which, even with the supply turned off, can hold their possibly lethal charge for a couple of minutes or more.

In our supply, there are exposed live mains conductors just below the lid, which could easily produce a fatal shock. Beware, other computer power supplies will certainly have similar hazards inside.

Make sure that your modifications do not interfere with the mains isolation of the PC board inside. As you can see from the internal photo of our supply, there is a row of transformers and optocouplers down the middle which form the isolation barrier between the high-voltage and low-voltage circuitry.

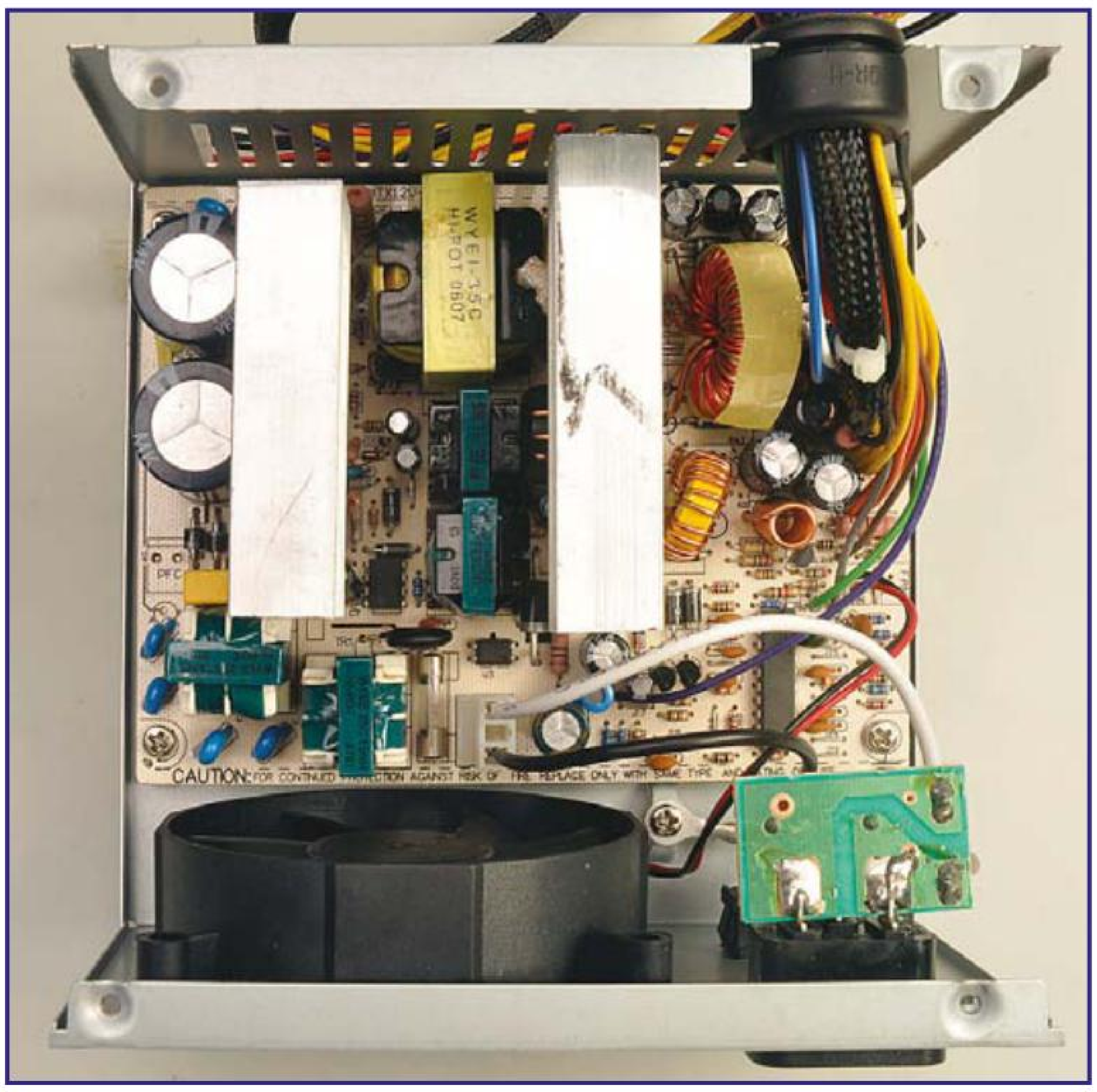
The high-voltage section contains the large mains filter capacitors. In this case they are rated at 200V DC and are connected in series (with parallel high value resistors) to handle the 325V or so which results from rectifying 230V AC.

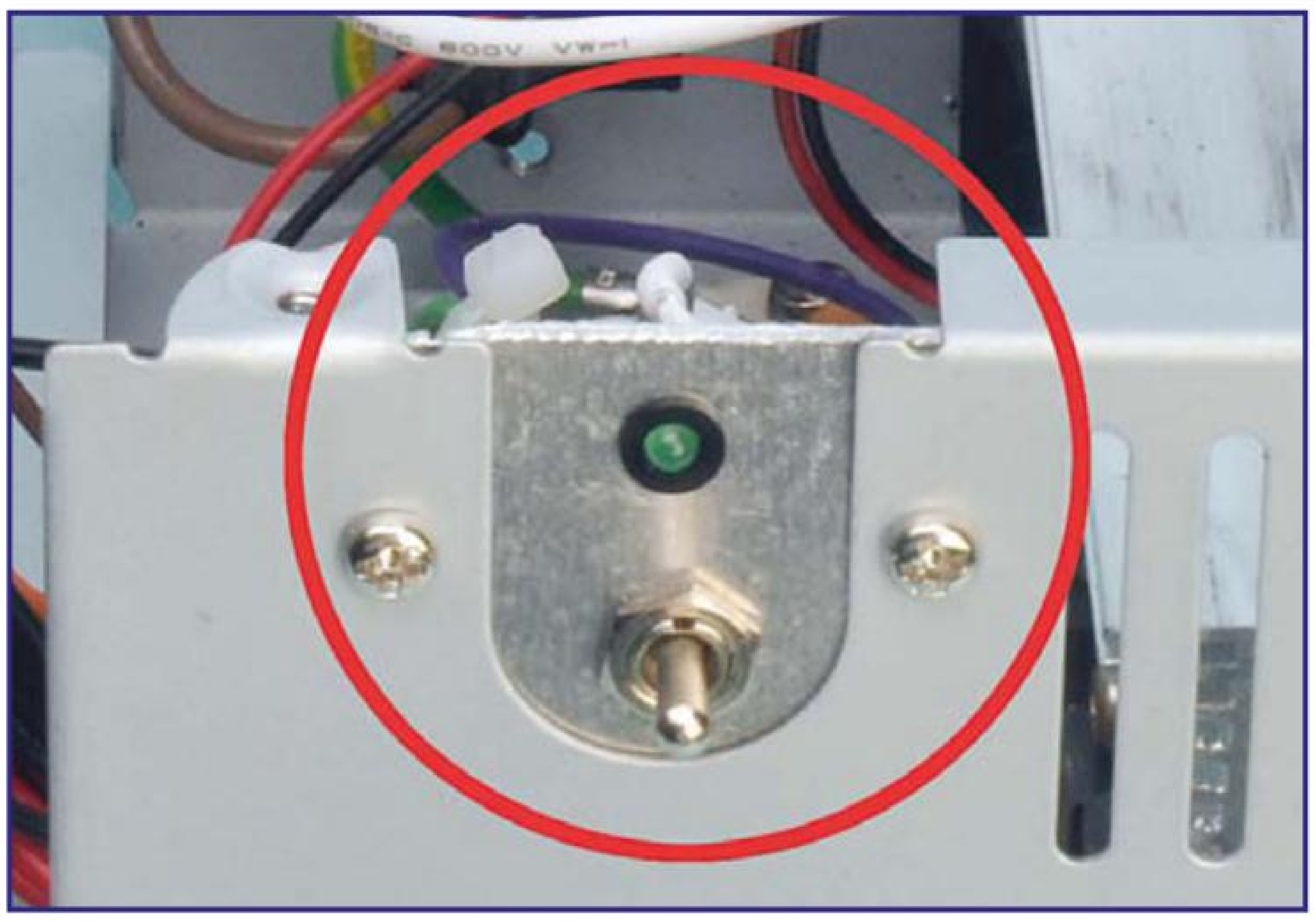
Do not mount any binding posts, switches or other components over or around this area. It is essential that the low-voltage side of the supply cannot short against a mains conductor and become live. This includes any heatsinks in the mains section; they may be live!

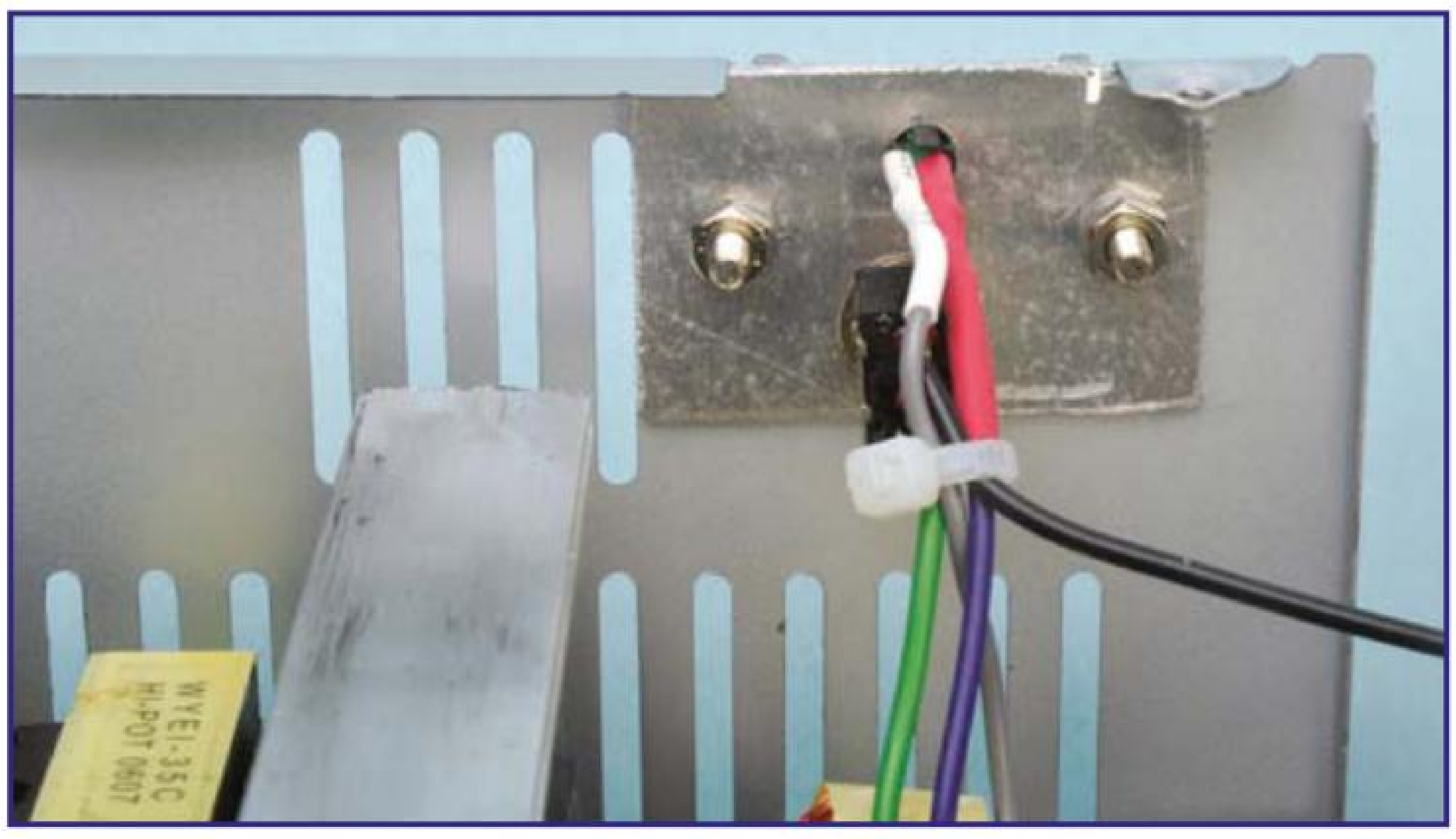
Start by opening up the supply (unplugged, of course). You may need to remove one or more stickers to expose screw heads, before this is possible. The lid will typically be held on using four Phillips head screws – undo them and it should come off.

Usually, the lid clamps the grommet which holds the bundle of low-voltage carrying wires where it exits the supply. Lift the bundle out of the case and remove the grommet.

Because the wire colour coding can vary between supplies, check yours against the list in Table 1. Now that you can see the PC board, if there are







In the original supply, all the low voltage cables emerge through a hole in the case (top right of above pic), held in place by a cord-grip grommet. In the modified supply, this hole is covered by a small piece of aluminum which contains a 'standby' power switch and an LED connected via a 390Ω resistor to one of the low voltage terminals

any silk-screened descriptions where the wires are soldered, check that they match this list. **Do not proceed until you are sure of the function of each wire!**

Metalwork

With the lid off and the low voltage wires loose, you can now determine where to mount the various additional components and drill the holes. As you can see from the photos, we decided to mount a standby switch and indicator LED on our supply, but these parts are optional. In fact, the bare minimum supply requires the addition of just two binding posts, although most constructors will want to use at least three (+12V, +5V and ground).

Aside from these components you will also need to fit a small metal plate to cover the now empty wire exit hole. This will prevent any accidents involving screwdrivers or fingers going inside the supply and possibly contacting dangerous voltages.

Cut a rectangle from an aluminium sheet or off-cut which will cover the opening and provide enough space for two or more mounting screws. File it to fit; remove any burrs or lips at the same time. Then, drill holes in both the panel and the supply case to take M3 (or larger) machine screws.

If you like, you can also drill holes to accept a switch and/or LED bezel in the plate, as we have. Ensure that with the cover in place, the lid closes properly, leaving no large gaps.

Binding posts

Now you must decide where to mount the binding posts. As mentioned previously, it is dangerous to locate these above the portion of the board which carries mains potential. It is for this reason that we decided to mount all our additional components near the now-covered wire exit hole, adjacent to the low-voltage side of the PC board. Also, be careful that the bottom ends of the binding posts or the attached wires cannot short against any heatsinks.

Once you have selected the appropriate locations, use a centre punch (or a nail and a hammer) to mark them. Don't put them right up against the edge, as that will make assembly tricky. Space them apart sufficiently to give room for access to the binding post wire entry holes once they are in place (at least 16mm, more if possible).

Be gentle with the punch as the relatively thin steel can be bent easily. You just want a small depression to guide the drill. You can then proceed to drill the approximately 7mm binding post mounting holes. If you are fitting a switch and/or LED and have not already made holes for them, do so. De-burr all the holes using a larger drill bit.

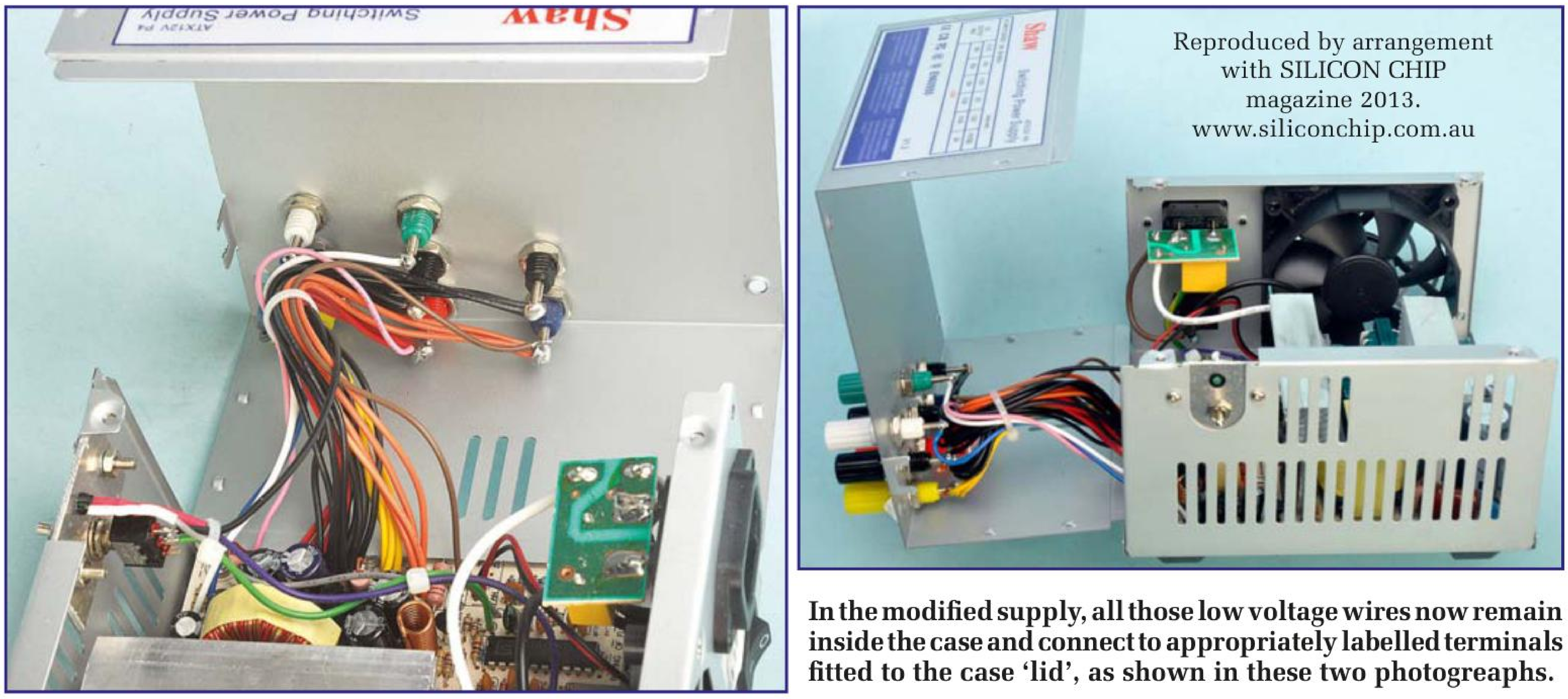
After that, install the binding posts. Unscrew the plastic cap so that you can orient them for good access to the wire entry holes. This usually means facing the hole towards the nearest edge of the case or, for those posts in the middle, diagonally.

When you are satisfied, tighten the binding post nuts very firmly while preventing the posts from rotating. When you have finished, screw the plastic caps back down.

Now stick the rubber feet onto the bottom of the supply. **Don't use screw-on feet** – you would probably have to remove the main board from the case to get them in and it's possible that the screws could short to the bottom of the PC board and create a shock hazard.

Wiring it up

Referring to Table 1, cut off any wires which are no longer necessary. Do this as close to the PC board as possible so that the wire stubs are not free to flex and contact any other wires or components. Ideally, there should be no more than about 5mm of each wire



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In the modified supply, all those low voltage wires now remain inside the case and connect to appropriately labelled terminals fitted to the case 'lid', as shown in these two photogreaphs.

left. Cut the connectors off the wires you will be keeping, as close to the connector as possible (to ensure the wires are long enough).

The reason that we suggest retaining thirteen black wires is that one will be used for the on/off switch and the other twelve can be split into three groups of four and soldered to the ground posts that correspond to +12V, +5V and +3.3V. These are high current outputs and this prevents the return current from one affecting the other voltages. If you are not providing all three outputs, you don't need as many ground wires.

If you are installing a switch, cut the green wire and one of the black wires so that they are just long enough to reach its terminals, strip the ends and solder them to it. They should be attached so that when the switch is in the 'on' position, these wires will be connected. Otherwise, cut the wires short, solder them together and heatshrink the junction.

If you are installing an LED, trim its anode (the longer lead) and solder the 390Ω resistor to it. Then trim the grey and purple wires so that they will reach the LED leads and strip the ends. Solder the purple wire to the 390Ω resistor and the grey wire to the cathode lead, then heatshrink both and push the LED and bezel through the hole you made earlier.

With this arrangement, the LED lights when the supply is in standby (ie, it has mains power but it is off) and when it is on but overloaded; otherwise it is off. You can arrange for it to light under other circumstances. For example, if you want it to be on whenever mains power is applied, connect the cathode to a black wire (ground) rather than grey. We shall leave other possibilities up to the reader.

Now place the lid upside-down, with the binding posts near to where the low voltage wires exit the PC board (see photo). Remove any small nuts which may be screwed on to the exposed binding posts shafts. Trim the remaining wires so that they will reach the appropriate binding posts. If you are not sure which wires go where, refer to Table 1.

There are a couple of tricks here. First, make them about 20mm longer than necessary to allow for stripping the ends. Second, you need to check to make sure that once the wires are soldered to the binding posts, you can actually manoeuvre the lid into place. This requires leaving a little slack in them. You can see from our photos how much extra length we allowed.

Before proceeding, check if your supply has pink (+5V sense) or brown (+3.3V sense) wires. If so, they must be soldered to the same point as the red (+5V) and orange (+3.3V) wires respectively. The easiest way to do this is to twist them together, as explained below. If you are not using one or both of these rails for an output, you must still connect the corresponding sense wires to at least one output wire (and heatshrink the junction).

Strip 20mm of insulation off the end of each wire and twist the strands together tightly. Wrap them around the binding post as many times as possible and flow solder onto the junction. For binding posts where more than one

Table 1 – ATX power supply wire colour codes

Colour	*Meaning*	*Number to keep (if possible)*
Black	Ground	13
Yellow	+12V	4
Red	+5V	4
Pink	+5V sense (optional)	1
Orange	+3.3V	4
Brown	+3.3V sense (optional)	1
Blue	–12V	1
White	-5V (optional)	1
Green	On/off switch (input, active low)	1
Purple	+5V standby	1
Grey	Power good (5V, active high)	1

wire is attached, twist all the wires together into a single, large bundle before wrapping it around the post; this is much easier than trying to solder them individually.

Make sure that the wires do not move as you solder them and use enough solder to fully envelop the joint. Stop heating as soon as the joint has been made, or you'll risk damaging the wire insulation.

Use small cable ties to hold the switch and LED wires in place, so that they cannot possibly come loose and contact any high voltage components. Wrap another cable tie around the bundle of wires connecting to the binding posts so that if one comes loose, it cannot flap around inside the supply.

Minimum load

Some ATX power supplies will not regulate their outputs correctly if there is no external load. This is not universal, the supply we used does not have this requirement. If yours does and you do not attach a dummy load, either the output voltages will be too high or the supply will not start up properly. If you are not sure about your supply, you can proceed to the testing step and return here if either condition occurs.

The 5V rail is the most likely to require a dummy load. Usually, this rail is regulated and the others just track it. However, it is possible that some computer supplies regulate the rails separately, and in this case each positive output will require a load.

While minimum load requirements will vary, the following 5W resistors between the output and ground should be sufficient in most cases: for the 5V rail, 27Ω; for the 12V rail, 150Ω and for the 3.3V rail, 15Ω. These resistors can be soldered between the binding post terminals.

Testing and completion

Before proceeding, check that all your solder joints are solid and that they are either insulated or cannot possibly contact any exposed metal inside the supply. If you have placed the binding posts correctly you will not need to insulate them, but all other joints should be heatshrinked.

Next, screw the lid in place. As you fit it, take care that the wire bundles are not squashed against any components.

Connect a multimeter set on volts mode between the +5V output and ground. Banana-plug-to-banana-plug leads come in very handy in this type of situation. If you have several multimeters, connect them to the other outputs. Plug an IEC power lead into the supply, flip the standby switch to on (if fitted) and then plug the mains in and switch it on.

Check that the output quickly rises to 5V (or thereabouts) and stays there. If it does not, immediately switch the supply off, disconnect it from mains and check your work. If you did not attach a load to the 5V rail then it is possible your supply requires a load; so follow the preceding instructions.

Assuming that all is well, you can check the other outputs and make sure they are correct. If you installed a standby switch, you can also check that it works and that the LED (if installed) behaves as expected.

Finally, it is a good idea to attach adhesive labels to indicate the voltage and current available at each output. You may remember the colour coding now, but it's easy to forget in future.

A label printing machine will result in a neat and legible result, although we found we had to cut the labels up to get the spacing correct. An alternative would be a label prepared on your computer and possibly laminated to protect it. ***EPE***

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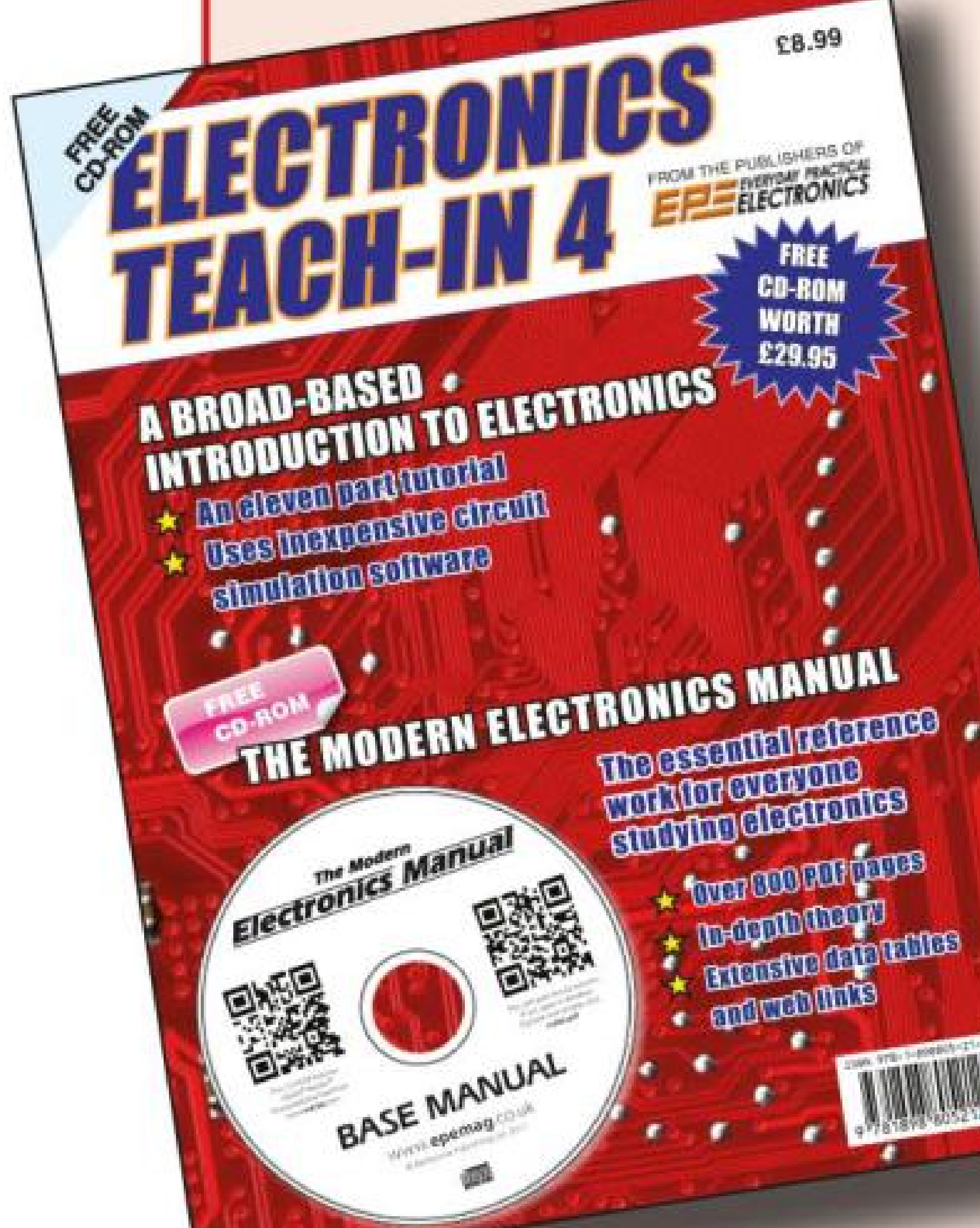
ELECTRONICS TEACH-IN 4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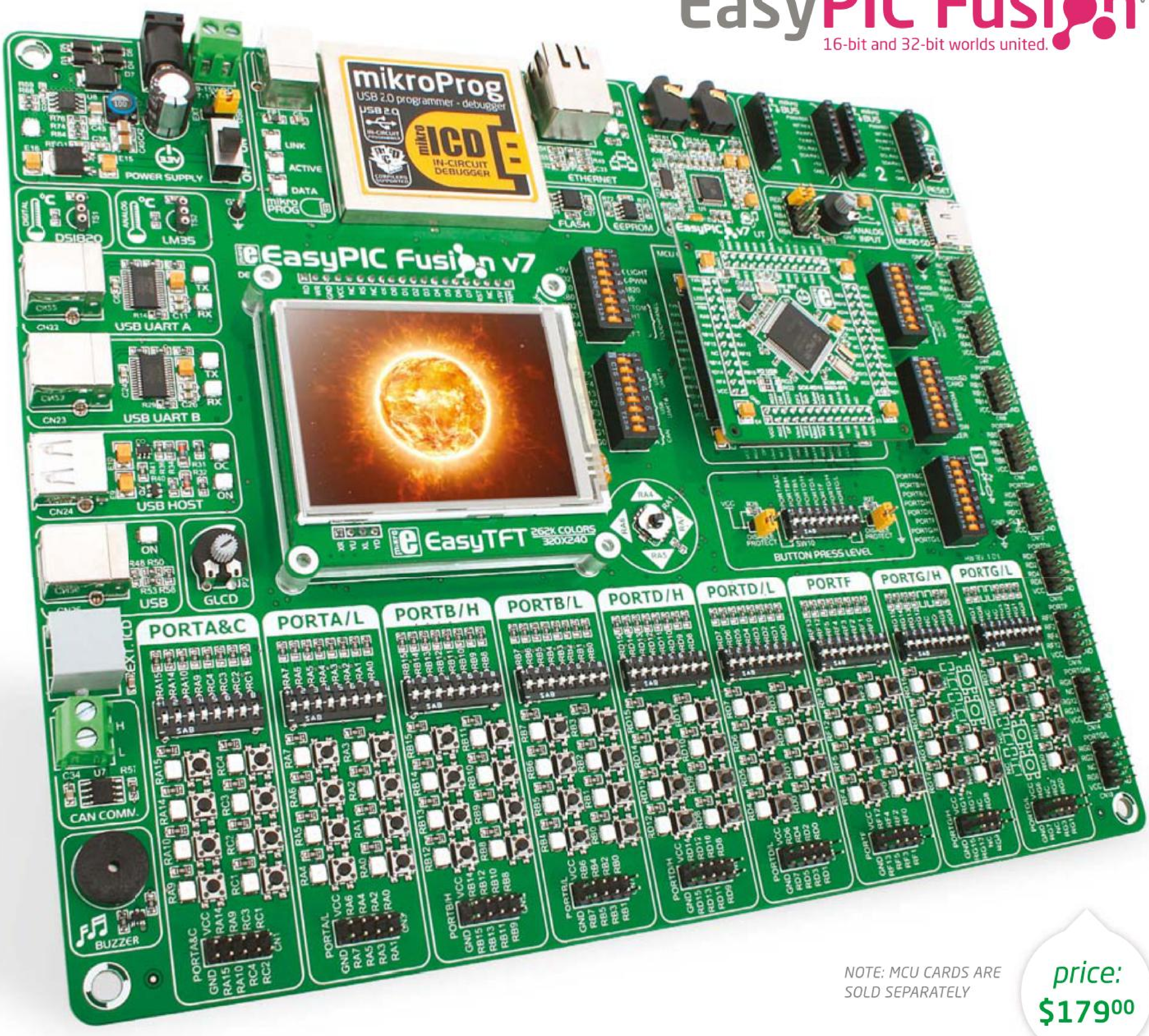
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GLCD
DS1820
LM35
FLASH
EEPROM
CAN COMM.
BUZZER
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Jump Start

By Mike and Richard Tooley

Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series has a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages in this issue).

Each of our Jump Start *circuits include the following features:*

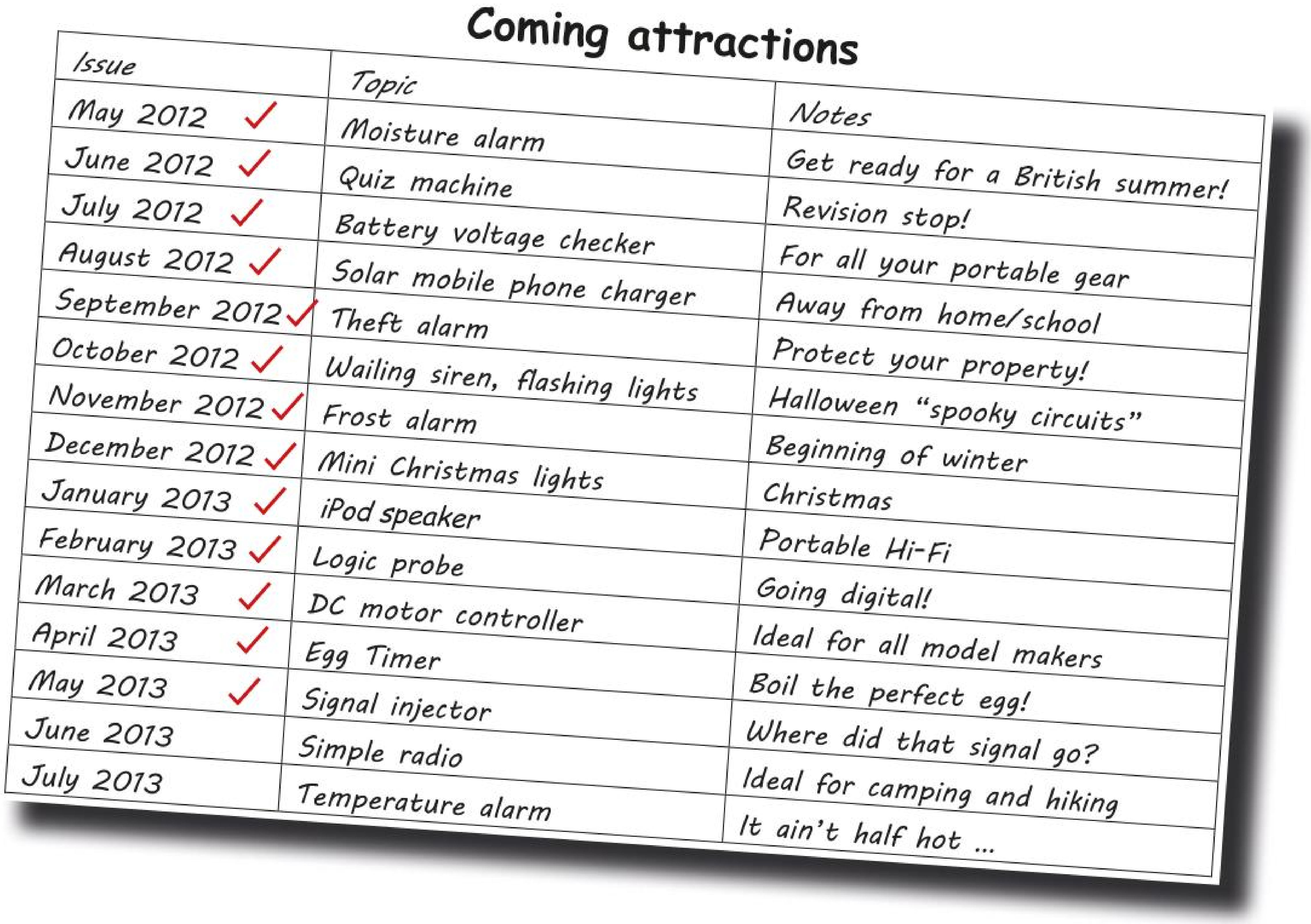
- ***Under the hood* –** provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes* –** has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard* –** used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real* –** introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further* –** provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery* –** shows how we developed and built each of the projects.

In this month's Jump Start, *we describe another simple but useful piece of test equipment in the form of a hand-held probe that can be used to inject and trace signals in both analogue and digital circuits. Our* Signal Injector Probe *uses only one common CMOS integrated circuit, and to keep things really simple, it derives its power supply from the circuit under investigation.*

Under the hood

The simplified block schematic of our *Signal Injector Probe* is shown in Fig.1. The circuit comprises two buffered square wave oscillator stages and a switched attenuator. The two oscillators can be individually adjusted in frequency with one set to a 'low' frequency (typically 400Hz) and the other to a 'high' frequency (typically 1kHz).

This allows circuit testing at two different frequencies and with two different selectable output levels (nominally 1V and 100mV peak-to-peak). The *Signal Injector Probe* can be easily modified for use with digital logic (rather than with analogue or mixed signals), as described later.



Coming attractions

Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012 ✓	Solar mobile phone charger	Away from home/school
September 2012 ✓	Theft alarm	Protect your property!
October 2012 ✓	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012 ✓	Frost alarm	Beginning of winter
December 2012 ✓	Mini Christmas lights	Christmas
January 2013 ✓	iPod speaker	Portable Hi-Fi
February 2013 ✓	Logic probe	Going digital!
March 2013 ✓	DC motor controller	Ideal for all model makers
April 2013 ✓	Egg Timer	Boil the perfect egg!
May 2013 ✓	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

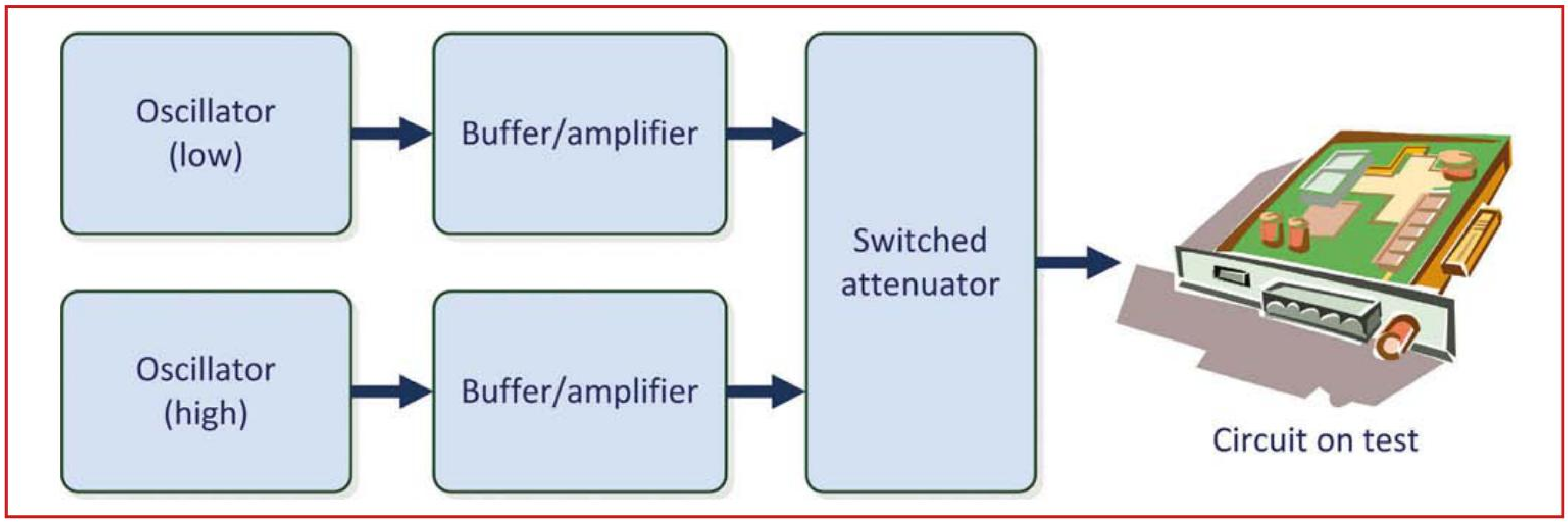


Fig.1. Simplified block schematic of our *Signal injector*

The power supply for the *Signal Injector Probe* is derived directly from the circuit under test, and can be any DC voltage in the range 5V to 15V at a current of less than 20mA. Alternatively, a single 9V (PP3 type) battery can be used to provide power for the *Signal Injector*, provided that a separate 'ground' connection is made to the circuit on test.

Design notes

The two square wave oscillators are based on a simple Schmitt oscillator/buffer arrangement like that shown in Fig.2. The original 'Schmitt trigger' was invented in 1943 by US scientist Otto Schmitt, who showed how positive feedback could be combined with 'hysteresis' to improve the switching action of a circuit based on thermionic valves.

In the case of the (more modern) circuit shown in Fig.2, the first inverting stage, IC1, is configured as an oscillator, with feedback from the output to the input via resistor *R*. The second inverter, IC2, acts as an inverting buffer. If you're not familiar with oscillators, you can simply think of them as a circuit block that provides an output signal without the need for any input – apart, of course, from a source of power!

In order to improve switching characteristics and reduce noise and false triggering a sub-family of common CMOS logic devices has in-built 'hysteresis'. One such device is the 40106 hex inverter shown in Fig.3. This device is supplied in a standard 14-pin dual-in-line package, and the six inverting gates have identical electrical characteristics. The most significant characteristic in this application is the large voltage range that exists between the lower and upper switching thresholds (shown as V_{lt} and V_{ut}, respectively in Fig.4).

Hysteresis

Fig.4 is a little complicated, so it is worth explaining this (and the notion of 'hysteresis') in a little more detail. Fig.4 shows input voltage plotted against supply voltage (V_{DD}). The supply voltage normally takes some value between +5V and +15V. We have shown a typical value of +9V marked with a dashed vertical line.

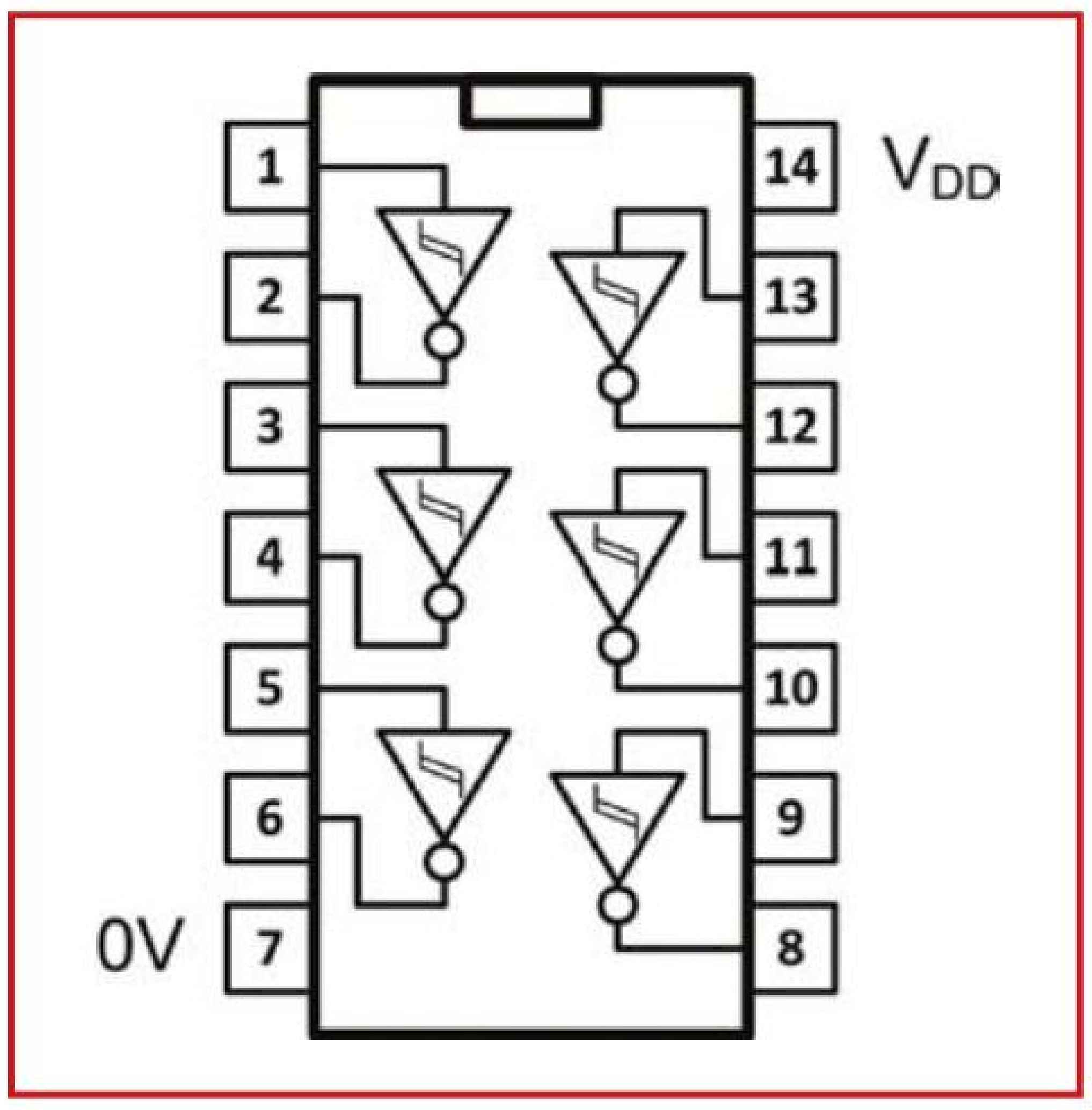


Fig.3. Pin connections for a 40106 hex Schmitt inverter

Now, if the gate input voltage is increased from 0V to some positive value, the change in voltage level will not be reflected in the output voltage of the gate until the upper threshold voltage (V_{ut}) is reached. We've marked this with a red 'blob' in Fig.4.

In the case of a +9V supply, this change will be recognised when the input voltage typically reaches a value of about +6.5V. At this point, the output voltage of the gate (which will previously have been 'high', due to the inverting action of the gate) will fall very rapidly to a low value.

If the input voltage is now reduced (ie, back towards 0V), the change in input voltage will not be recognised until the input voltage has fallen to the lower threshold voltage (V_{lt}). We've marked this with a green 'blob' in Fig.4.

In the case of a +9V supply, this change will be recognised when the input voltage has fallen back to about +2.5V. At this point, the output voltage produced by the inverting gate will rise very rapidly to a value very close to +9V (ie, very close to V_{DD}).

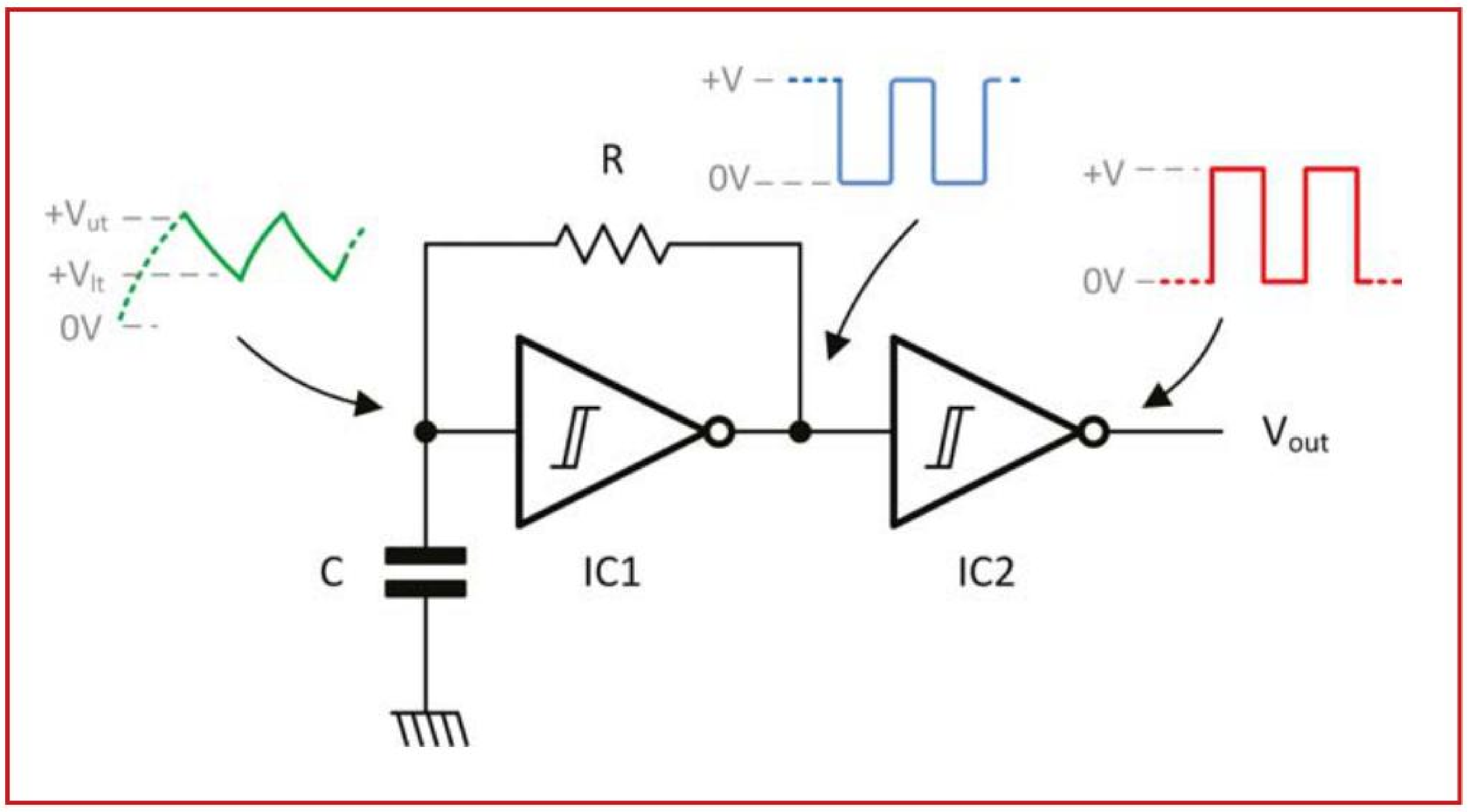


Fig.2. Basic Schmitt oscillator/buffer stage

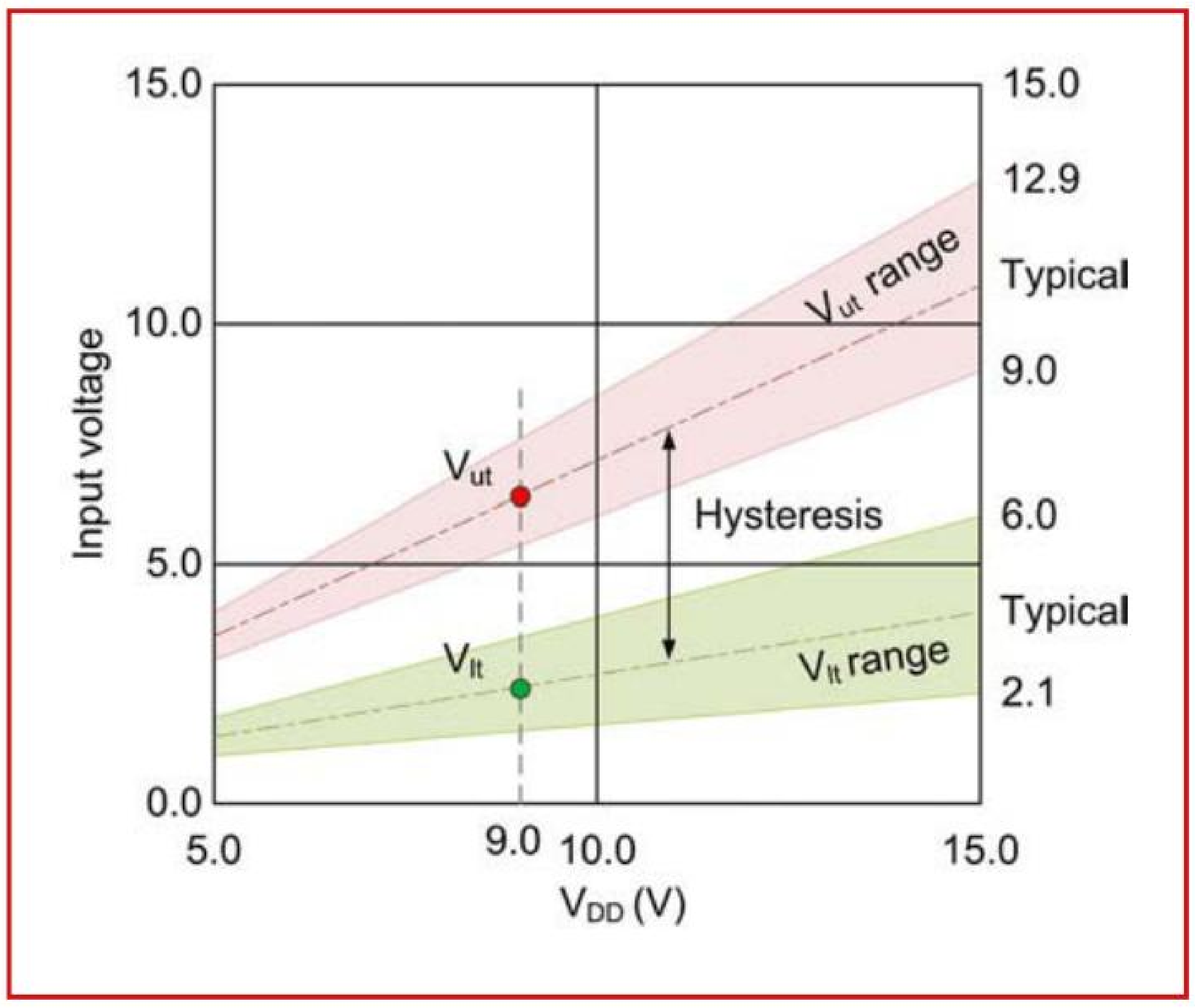


Fig.4. Input threshold voltages for a 40106 device

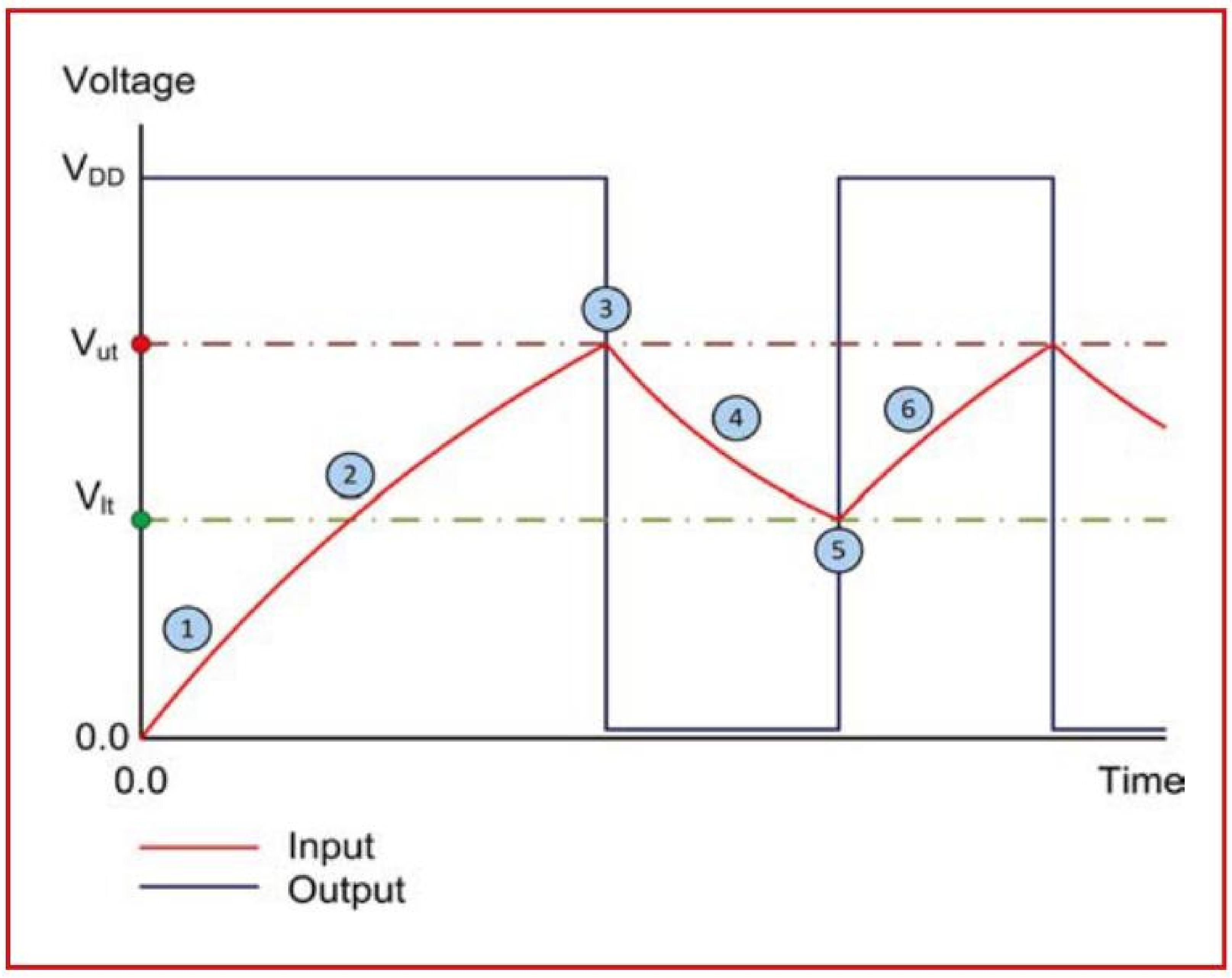


Fig.5. Build-up of oscillation in the circuit shown in Fig.2

This delay in recognising a change of voltage at the input (which we refer to as 'hysteresis') makes the inverting gate very useful in a number of applications, including simple square wave oscillators that require only a resistor and capacitor in order to determine the frequency of oscillation.

Fig.5 shows how oscillation starts in the circuit shown in Fig.2. The capacitor, *C*, will initially be *uncharged*, and this will hold the input voltage of IC1 'low'. This, in turn, will cause the output voltage of IC1 to go 'high'. The capacitor will then receive charge via resistor *R* and the voltage at the input will rise exponentially (see point 1). A little later, the input voltage will rise beyond the lower threshold voltage, V_{lt} (see point 2), but nothing will happen at the output when this voltage is reached.

Eventually, the capacitor voltage will reach the upper threshold, V_{ut} (see point 3), at which point the output voltage will suddenly fall to zero and the capacitor will begin to discharge through resistor *R* (see point 4). At some later time, the input voltage will have fallen to the lower threshold voltage, V_{lt} (see point 5). When this voltage is reached, the output will rapidly revert to its 'high' state and the capacitor will start to recharge (see point 6). The cycle of charging and discharging will then repeat indefinitely and our oscillation will be continuous.

Get real

You should now be ready to check the operation of the Schmitt oscillator used in the *Signal Injector Probe* for yourself. Fig.6 shows a simple single-stage inverter and corresponding output waveforms. If you use Circuit Wizard to simulate this circuit and display the input and output waveforms (note the red and blue oscilloscope probes) you will find that the waveforms resemble those that we showed earlier in Fig.5.

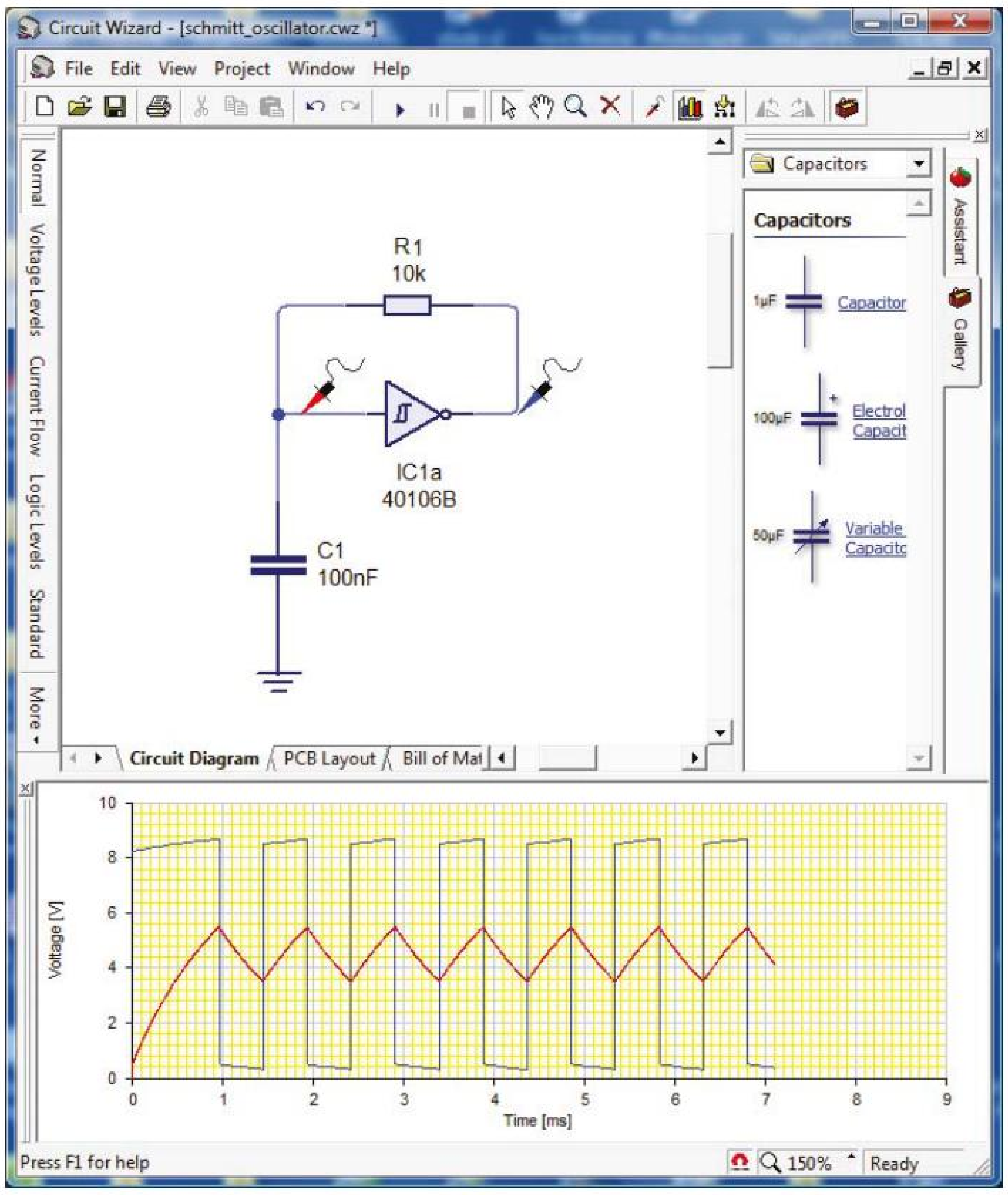

Circuit Wizard - [schmitt_oscillator.cwz *]
File Edit View Project Window Help
Normal
Voltage Levels
Current Flow
Logic Levels
Standard
More
R1
10k
IC1a
40106B
C1
100nF
Capacitors
Capacitors
1µF
Capacitor
100µF
Electrol Capacit
50µF
Variable Capacitc
Assistant
Gallery
Circuit Diagram
PCB Layout
Bill of Mat
10
8
6
4
2
0
Voltage [V]
0
1
2
3
4
5
6
7
8
9
Time [ms]
Press F1 for help
150%
Ready

Fig.6. Single-stage 40106 oscillator modelled in Circuit Wizard

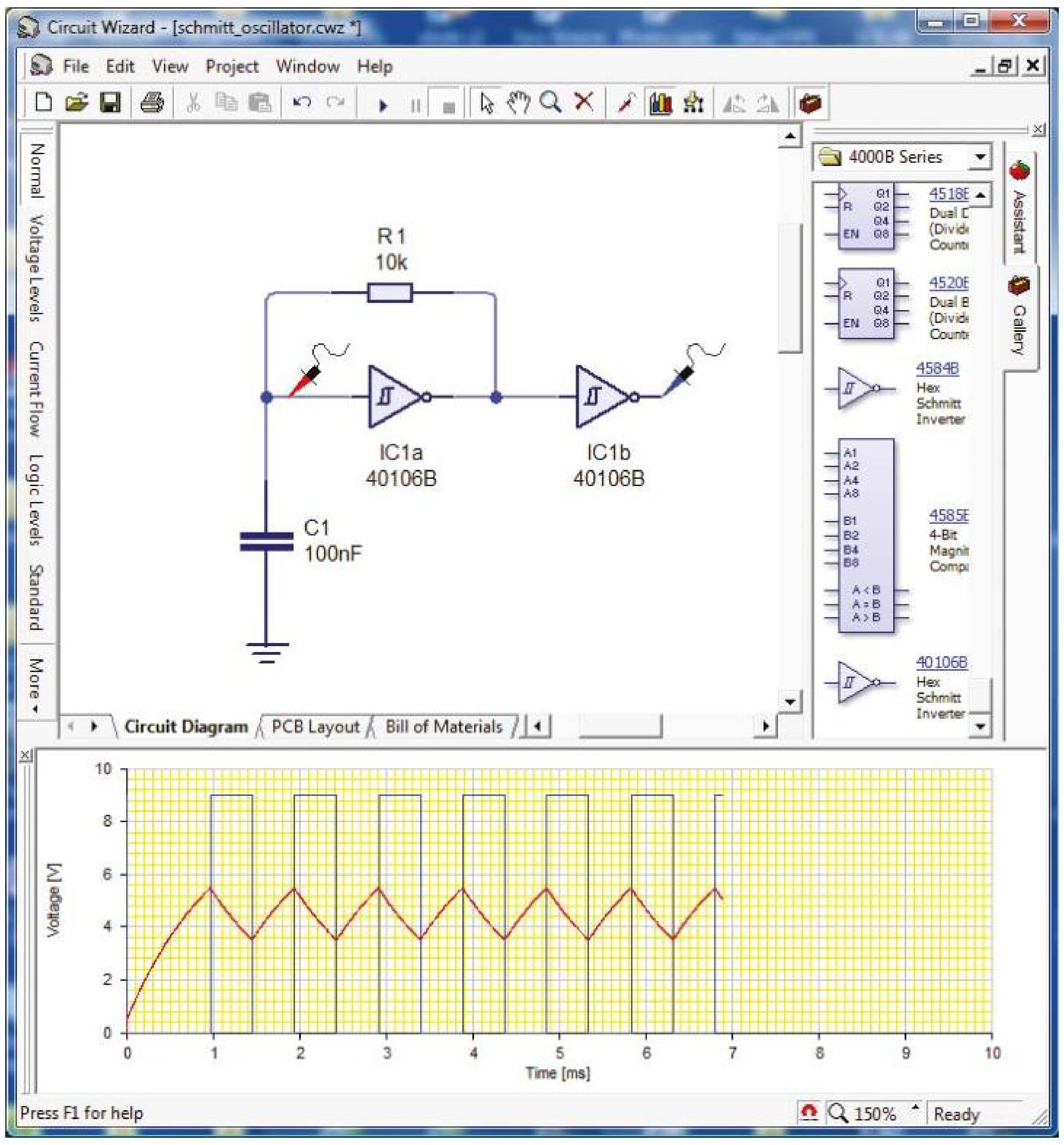
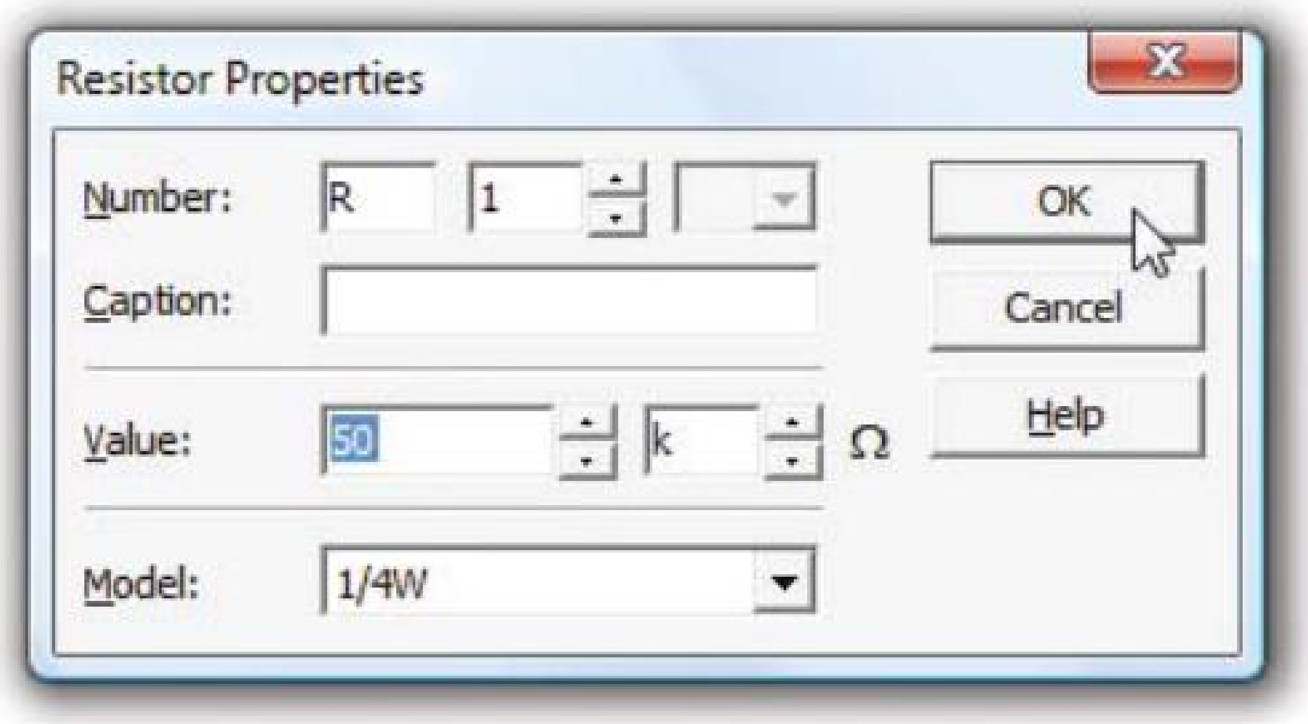

Circuit Wizard - [schmitt_oscillator.cwz *]
File Edit View Project Window Help
Normal
Voltage Levels
Current Flow
Logic Levels
Standard
More
R1
10k
IC1a
40106B
IC1b
40106B
C1
100nF
4000B Series
4518E
Dual D (Divid Count
4520E
Dual B (Divid Count
4584B
Hex Schmitt Inverter
4585E
4-Bit Magnit Compa
40106B
Hex Schmitt Inverter
Assistant
Gallery
Circuit Diagram
PCB Layout
Bill of Materials
10
8
6
4
2
0
Voltage [V]
0
1
2
3
4
5
6
7
8
9
10
Time [ms]
Press F1 for help
150%
Ready

Fig.7. Buffered 40106 oscillator modelled in Circuit Wizard

However, if you look closely at the output waveform (shown in blue) you will see that it is not quite perfect. To improve this waveform you can add the buffer stage, as shown in Fig.7. The output waveform will then be a near-perfect square wave.

It can be instructive to experiment with different values for *C* and *R*. If you right-click on the component that you wish to change (see Fig.8) you will be able to set a new value and observe the effect on the waveform. Note in particular, the new periodic time (and thus output frequency) produced by the oscillator circuit.

Finally, if you have some time to spare, it might be interesting to plot a graph showing periodic time or frequency plotted against the product of *C* and *R*. This will allow you to select a combination of component values for any desired output frequency (but note that the output frequency also varies with supply voltage and the particular threshold voltages for the integrated circuit that you use).


Resistor Properties

Number: R 1

Caption:

Value: 50 k Ω

Model: 1/4W

Fig.8. Using the Circuit Wizard 'Resistor Properties' dialogue to change the value of R1

Signal Injector Probe – using Circuit Wizard

NOW we're ready to start the process of converting the switched dual-frequency square wave generator shown in Fig.9 into something that we can put together for real. Fig.10 shows our circuit ready for PCB conversion. The only changes that we've made is to replace the two switches with three-pin single in-line (SIL) connectors. You'll find them in a folder under 'Connectors'.

When Circuit Wizard converts switches to a PCB, the default is a three-pin screw connector. However, in this case, we want to use a PCB-mounting slide switch (Fig.11) that very conveniently has the same pad layout as a SIL package. The idea is that with the switches mounted directly onto the PCB, we can create two small rectangular apertures in the case that will allow the end user to select the output amplitude and frequency.

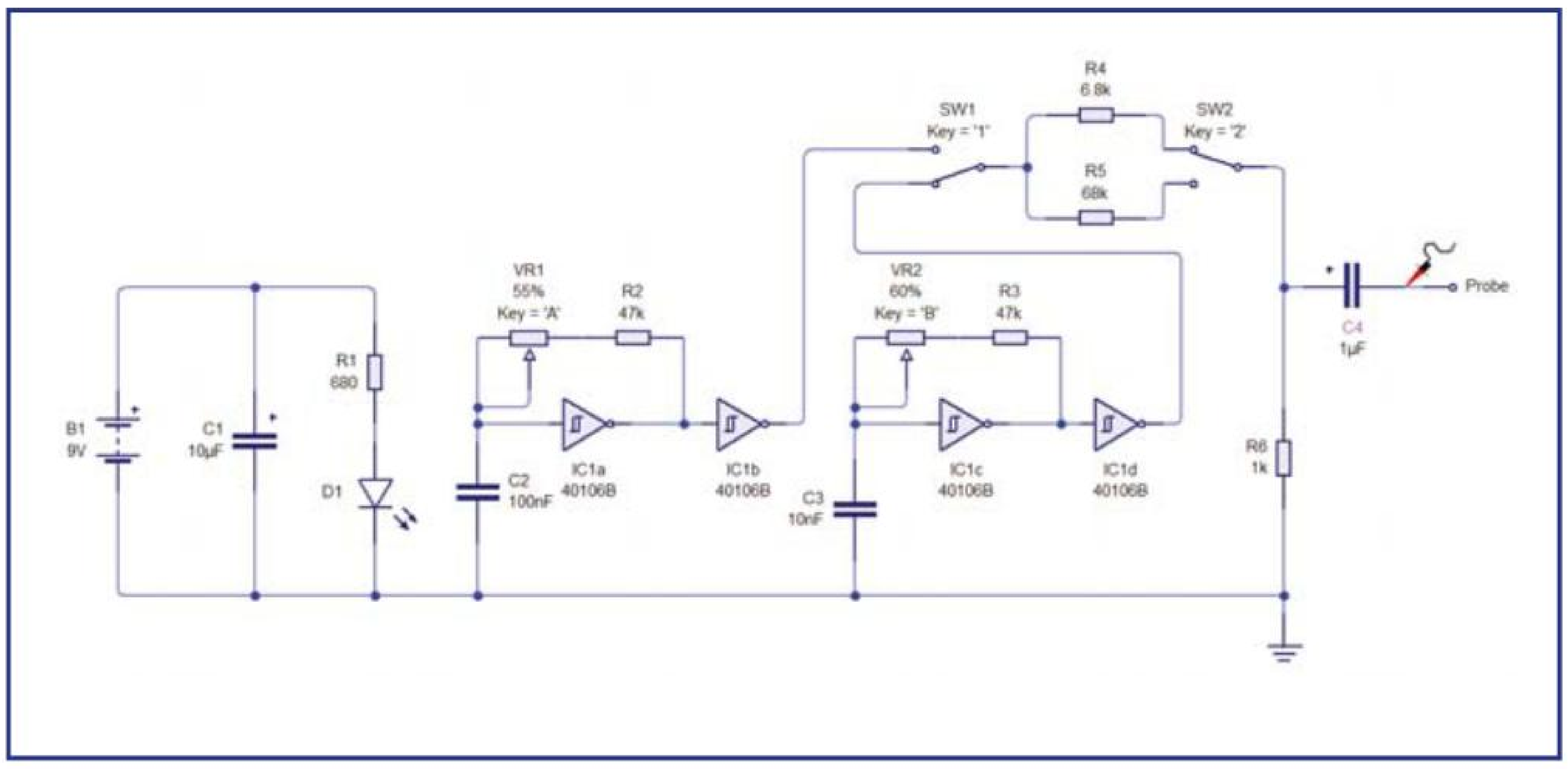
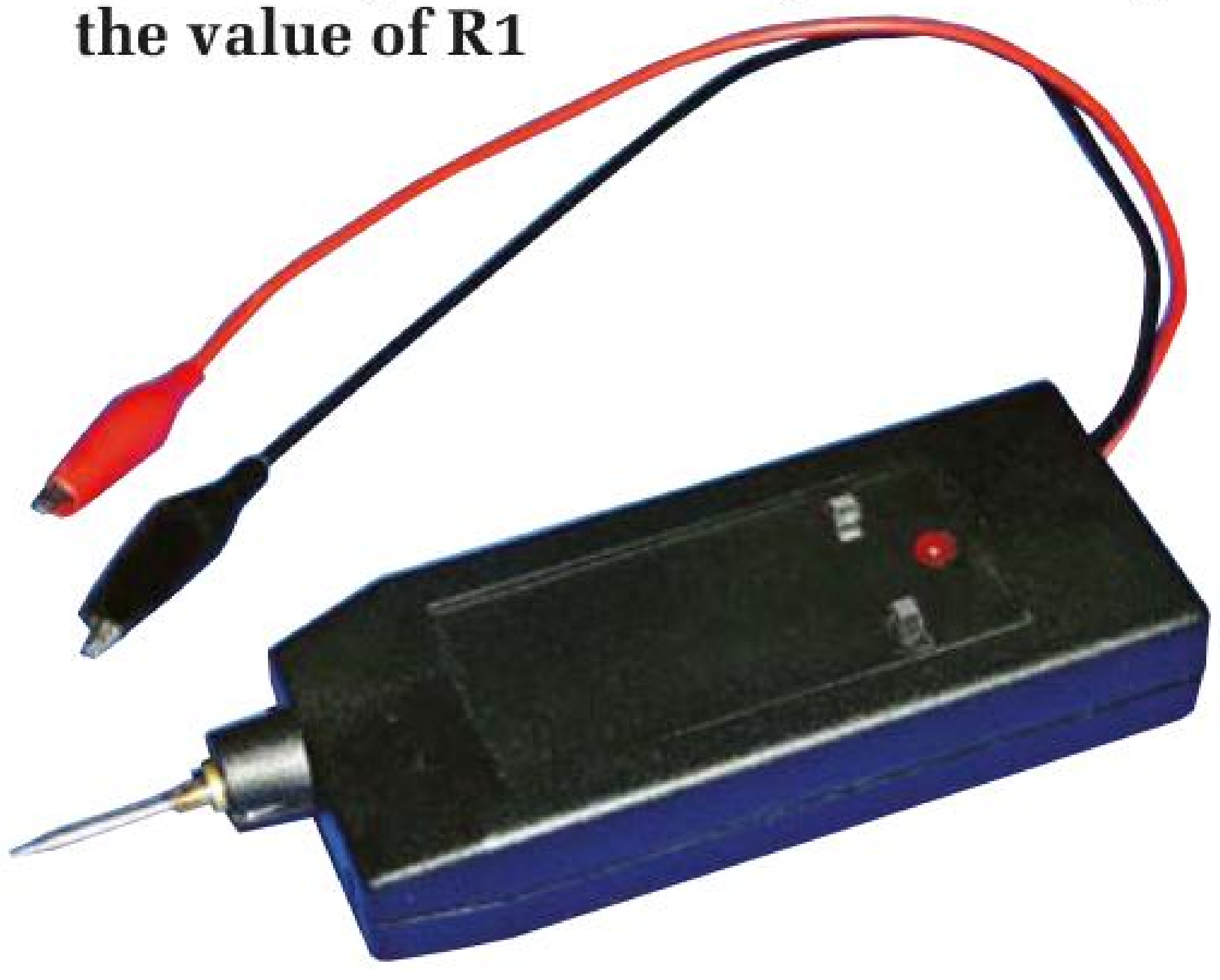


Fig.9. The original circuit schematic of our *Signal Injector Probe*

We have chosen to mount our prototype board in a pre-manufactured probe case (Rapid part number 31-0330). This is one of the larger hand-held probe cases that they sell, although it will still require some careful thinking and keen PCB routing skills to get the PCB to fit!

The case is good quality, and comes with a detachable faceplate (convenient for making the required holes for the LED and the two switches) and a brass probe. Alternatively, you could easily make your own probe case using vacuum forming techniques, or make use of a low-cost ABS case. In either case, it's important to check that the PCB will fit neatly into the case and the two slide switches can be conveniently accessed.



Circuit board

When working with smaller board sizes and thinner tracks you may well find that you need to reduce the grid spacing. Circuit Wizard's default spacing is 0.1in (consistent with much component pin geometry).

However, you may wish to reduce this if you need to run smaller tracks through tight spots. This can be achieved through View > Grid/Snap, as shown in Fig.12. It is inadvisable to turn off 'Snap to Grid' when drawing tracks, as this can make it difficult to ensure that connections are properly made.

Having said that, we have found it useful to work without snap when arranging the component labels on the silk screen layer, and have found it difficult to get them just where we want them. One area where Circuit Wizard is a little 'messy' is arranging the component identifiers and values. Often it will place them over other components and/or each other, or even off the board, making them unusable.

Obviously, this is of no consequence if you are not intending to, or indeed do not have the facility to, add a silk screen to your PCB. Indeed, you will notice that none of our physical boards have this.

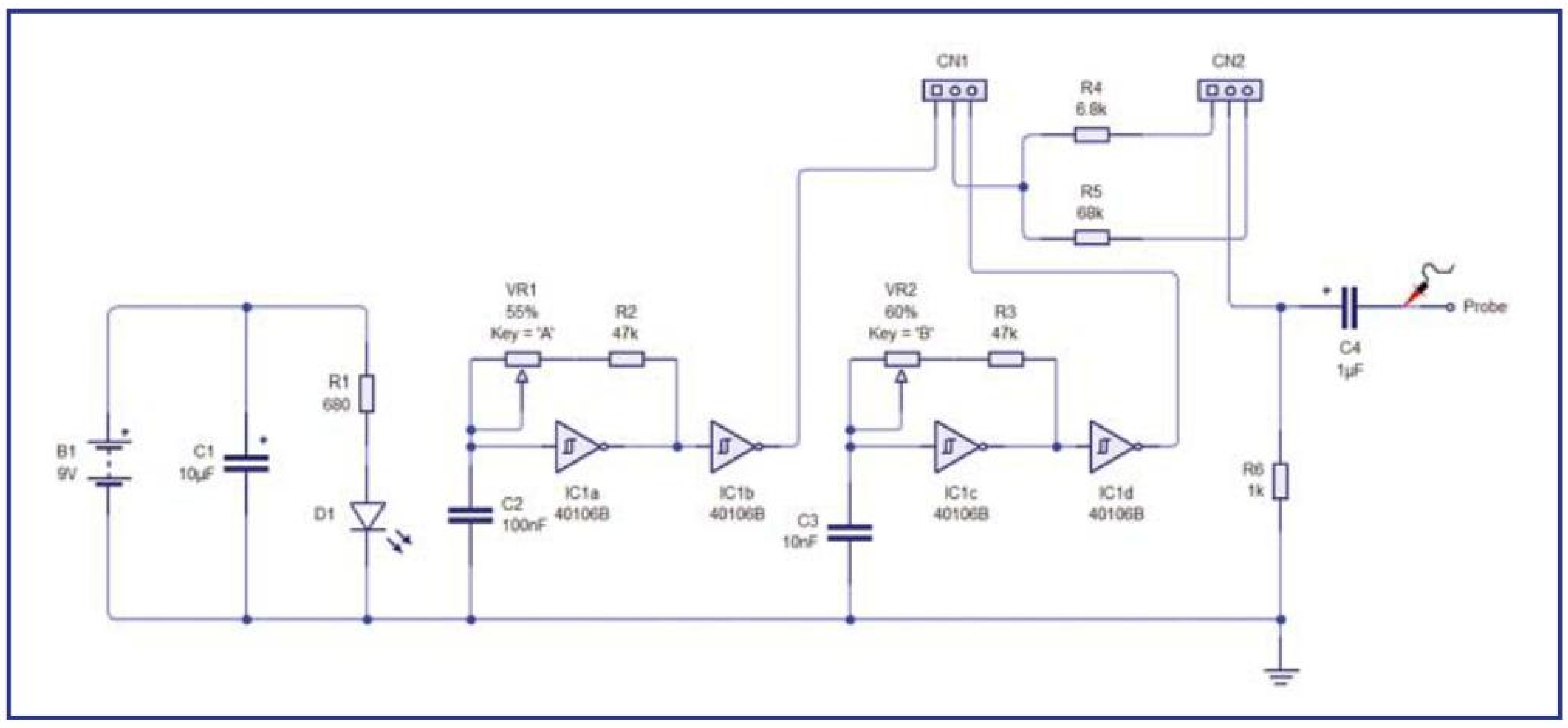


Fig.10. The complete PCB-ready circuit diagram of our *Signal Injector Probe*

However, we have found that the silk screen layer provides the best reference for assembling the PCB to identify the location of the components, and we recommend printing this out before assembly. Remember that very often the physical positions of the components on the circuit board differ from that of the schematic.

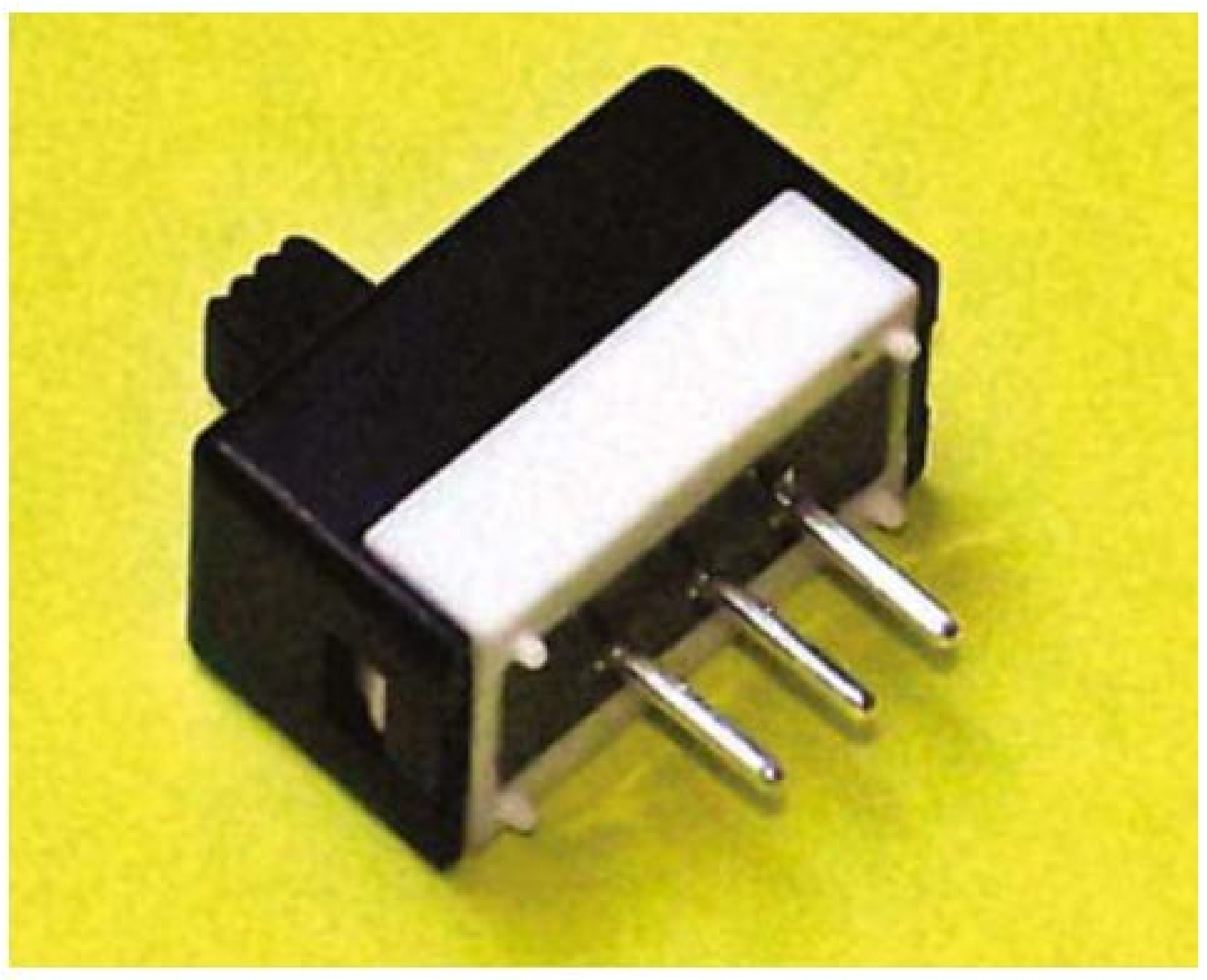


Fig.11. A PCB mounting slide-switch

To view or print the silk screen layer you need to click on the 'More' tab on the left-hand side of the screen (see Fig.13). When arranging your labels, make sure that you place the correct identifier and value by each component – it's very easy to confuse which label relates to which component if they are overlaid on each other. For example, the silk screen layer for our prototype signal injector is shown in Fig.14.

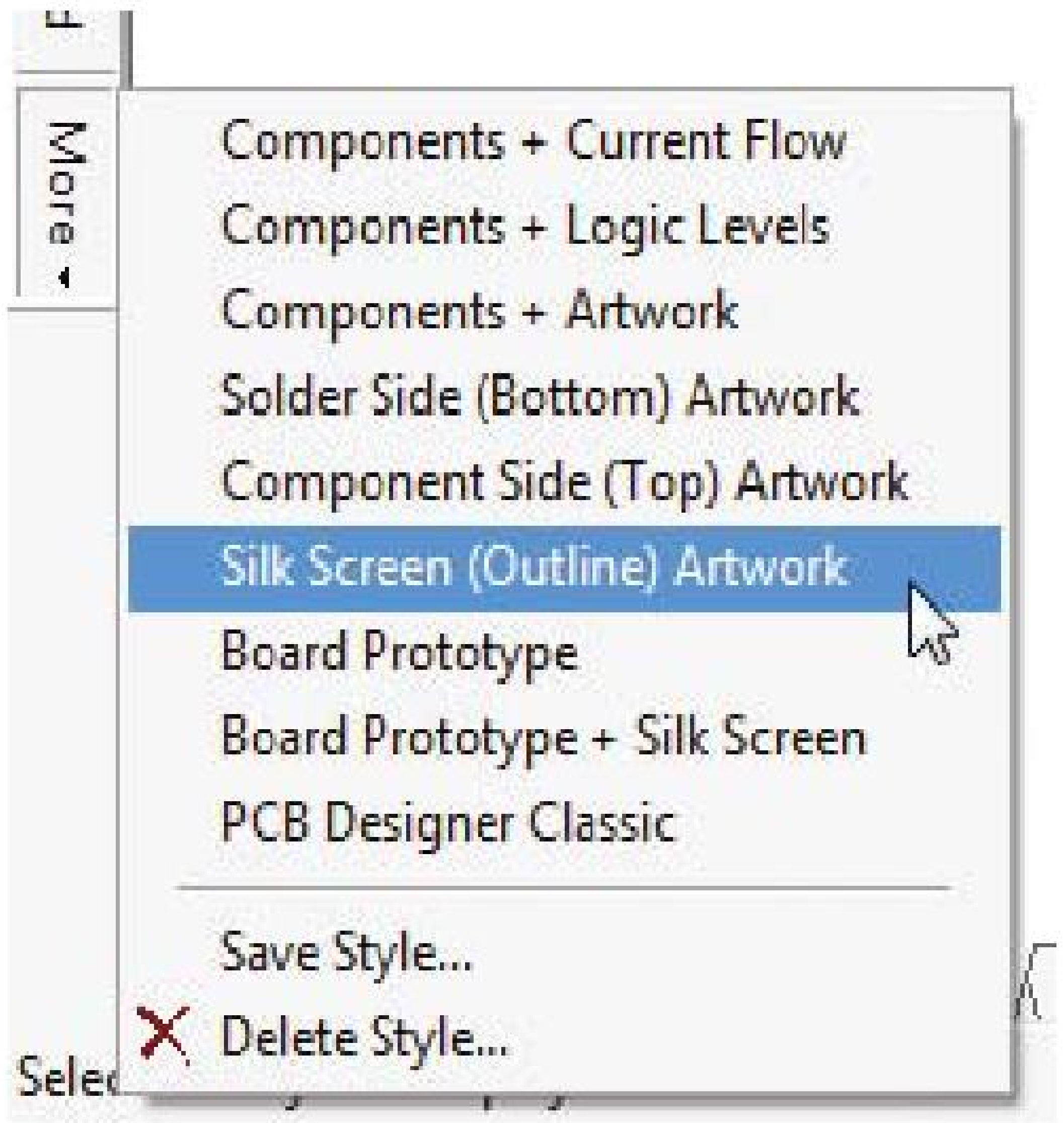

More
Components + Current Flow
Components + Logic Levels
Components + Artwork
Solder Side (Bottom) Artwork
Component Side (Top) Artwork
Silk Screen (Outline) Artwork
Board Prototype
Board Prototype + Silk Screen
PCB Designer Classic
Save Style...
Delete Style...
Selec

Fig.13. Circuit Wizard's select silk screen menu

Printed circuit board

Our PCB design is shown in Fig.15. We set the PCB size when converting to 2.8in (W) × 1.5in (H). This is easily specified using the PCB conversion wizard. These dimensions should fit snugly into the specified probe casing.

When designing the PCB, we had to think carefully about the positions of the two slide-switches and the LED, as they would protrude through the case. Therefore, these were placed appropriately before routing.

We also needed to consider the height of the radial electrolytic capacitors, which, in an upright position would be too tall to fit in the case. Therefore, we have allowed some additional space for them to be bent over on to their side (see Photo gallery).

A 5mm hole and two rectangular cut outs need to be made in the face plate. The PCB should fit neatly behind these holes and allow access to the switches. The PCB may be left 'floating' in the case (in practice the PCB is quite squashed in with the protruding controls/LEDs stopping movement). Alternatively, a couple of well-placed drops of hot melt gun glue, double-sided foam pads or Velcro pads could be used to provide a quick method of anchoring the board.

When in use, it is assumed that the power supply will be taken from the circuit/device that is being tested. Therefore, we have attached two crocodile clip terminated leads to our PCB. It is worth preparing these leads properly before soldering them to the PCB location marked by the two-way terminal block (note that there may be insufficient height clearance to fit this into the Rapid probe case); strip, twist, solder and trim them neatly. Additionally, tying a knot to the leads just inside of the hole in the case should provide some modest protection from the wires being pulled out.

Alternatively, a small plastic 'strain relief' can be made and then fitted in the small slot provided at the rear of the Rapid probe case.

Using the Signal Injector

The *Signal Injector Probe* is easy to use and the basic design is ideal for checking a wide variety of analogue and mixed logic circuits. The probe must first be connected to the supply rails (max. +15V) of the circuit on test, taking extra care to ensure correct polarity.

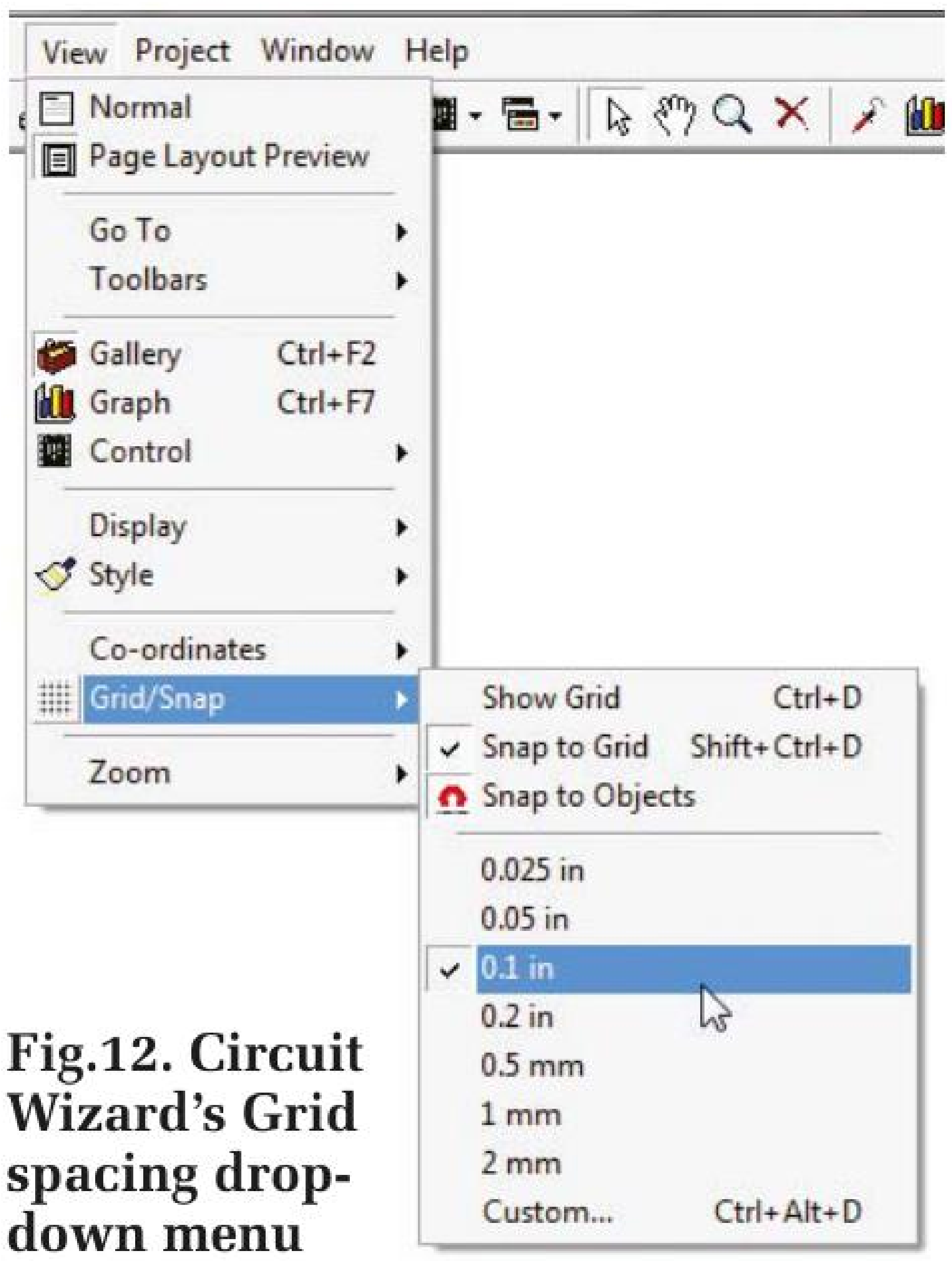

View
Project
Window
Help
Normal
Page Layout Preview
Go To
Toolbars
Gallery Ctrl+F2
Graph Ctrl+F7
Control
Display
Style
Co-ordinates
Grid/Snap
Zoom
Show Grid Ctrl+D
Snap to Grid Shift+Ctrl+D
Snap to Objects
0.025 in
0.05 in
0.1 in
0.2 in
0.5 mm
1 mm
2 mm
Custom... Ctrl+Alt+D

Fig.12. Circuit Wizard's Grid spacing drop-down menu

Next, the probe is moved from stage-to-stage in order to inject the test signal. If desired, the values of capacitors C1 and C2 can be changed to produce outputs over a frequency range from as little as 1Hz to over 100kHz.

Finally, if the *Probe* is only to be used with conventional digital logic (and not for analogue applications), the following changes will provide you with a logic-compatible output:

1. Replace C3 with a short-circuit link
2. Replace R3 with a fixed 100Ω resistor
3. Set SW2 to the 'high' position.

For more info:
www.tooley.co.uk/epe

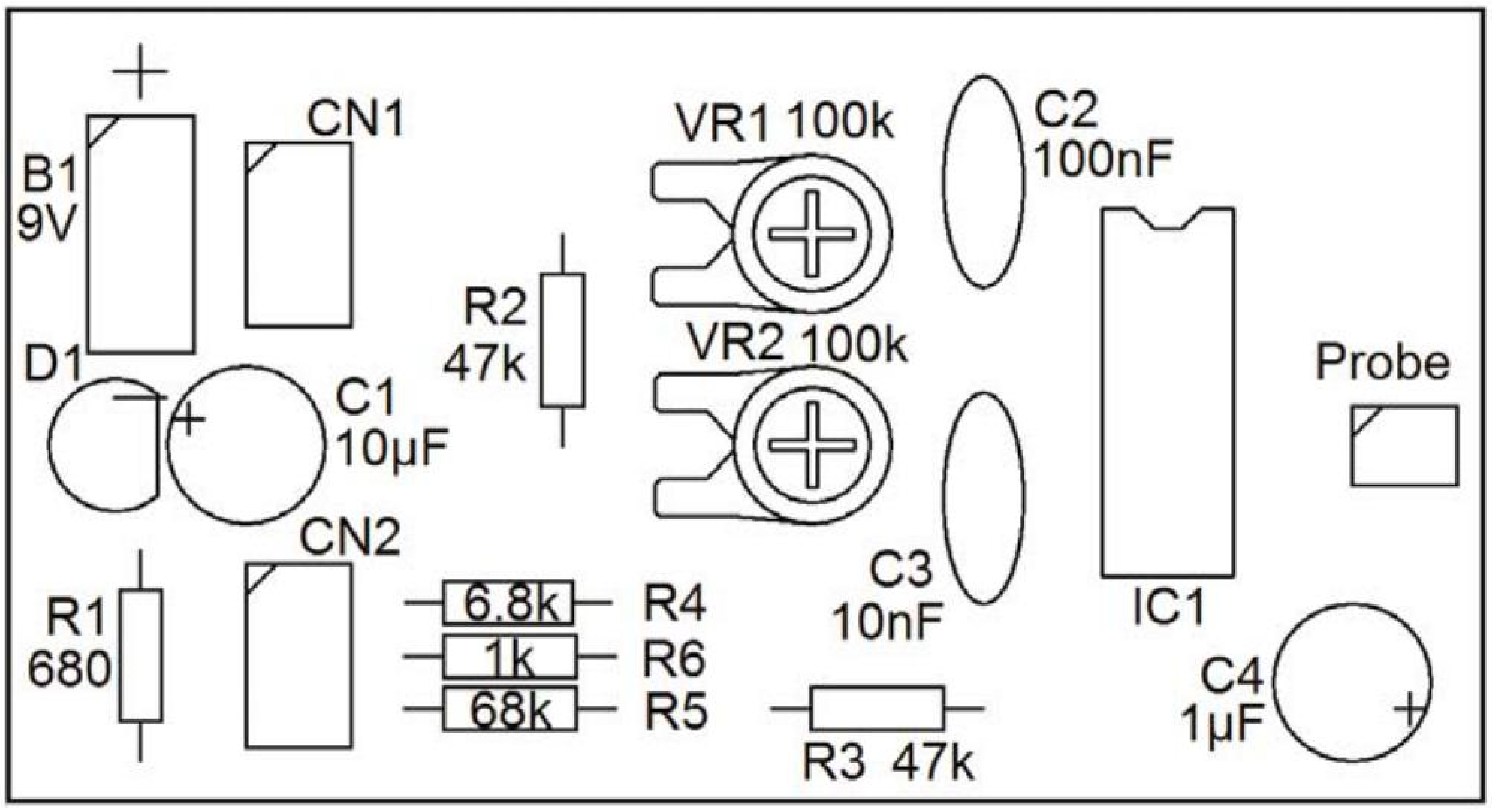

+
B1
9V
CN1
VR1 100k
C2
100nF
R2
47k
D1
+
C1
10µF
VR2 100k
Probe
CN2
R1
680
6.8k
1k
68k
R4
R6
R5
C3
10nF
IC1
C4
1µF
+
R3 47k

Fig.14. Silk screen for the *Signal Injector*

You will need...

Signal Injector Probe

1 PCB, code 900, available from the *EPE PCB Service*, size 71mm × 38mm
1 PCB terminal pin
2 insulated crocodile clips (one black and one red)
1 14-pin low-profile DIL socket
1 probe case, size 104mm × 44mm × 20mm (e.g. Rapid 31-0330)
2 PCB mounting slide-switches (see text)
2 3-pin single in-line (SIL) connectors (CN1, CN2)

Semiconductors
1 40106 hex Schmitt inverter (IC1)
1 Red LED (D1)

Resistors
1 680Ω (R1)
2 47kΩ (R2 and R3)
1 6.8kΩ (R4)
1 68kΩ (R5)
1 1kΩ (R6)
2 100kΩ PCB mounting preset potentiometers (VR1 and VR2)

Capacitors
1 10µF 25V radial electrolytic (C1)
1 100nF min. polyester (C2)
1 10nF min. polyester (C3)
1 1µF 50V radial electrolytic (C4)

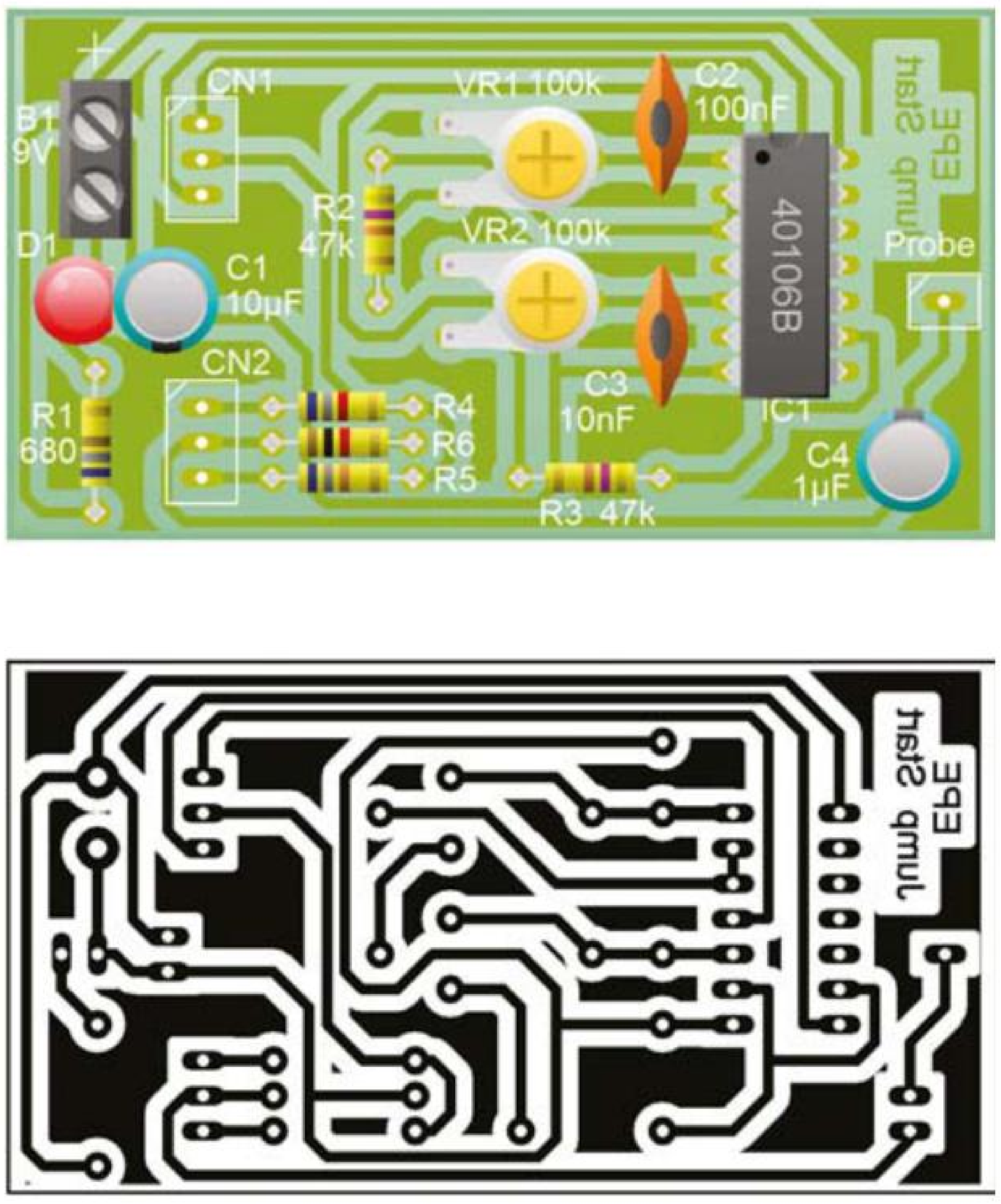


Fig.15. PCB design example (from top to bottom); component layout, and track layout viewed through the board. Final size is 71mm × 38mm

Photo gallery...

The Gallery is intended to show readers some of the techniques that they can put to use in the practical realisation of a design, such as PCB fabrication and laser cutting. This is very important in an educational context, where students are required to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding.

The techniques that we have used are available in nearly every secondary school and college in the country, and we believe that our series will provide teachers with a tremendously useful resource!

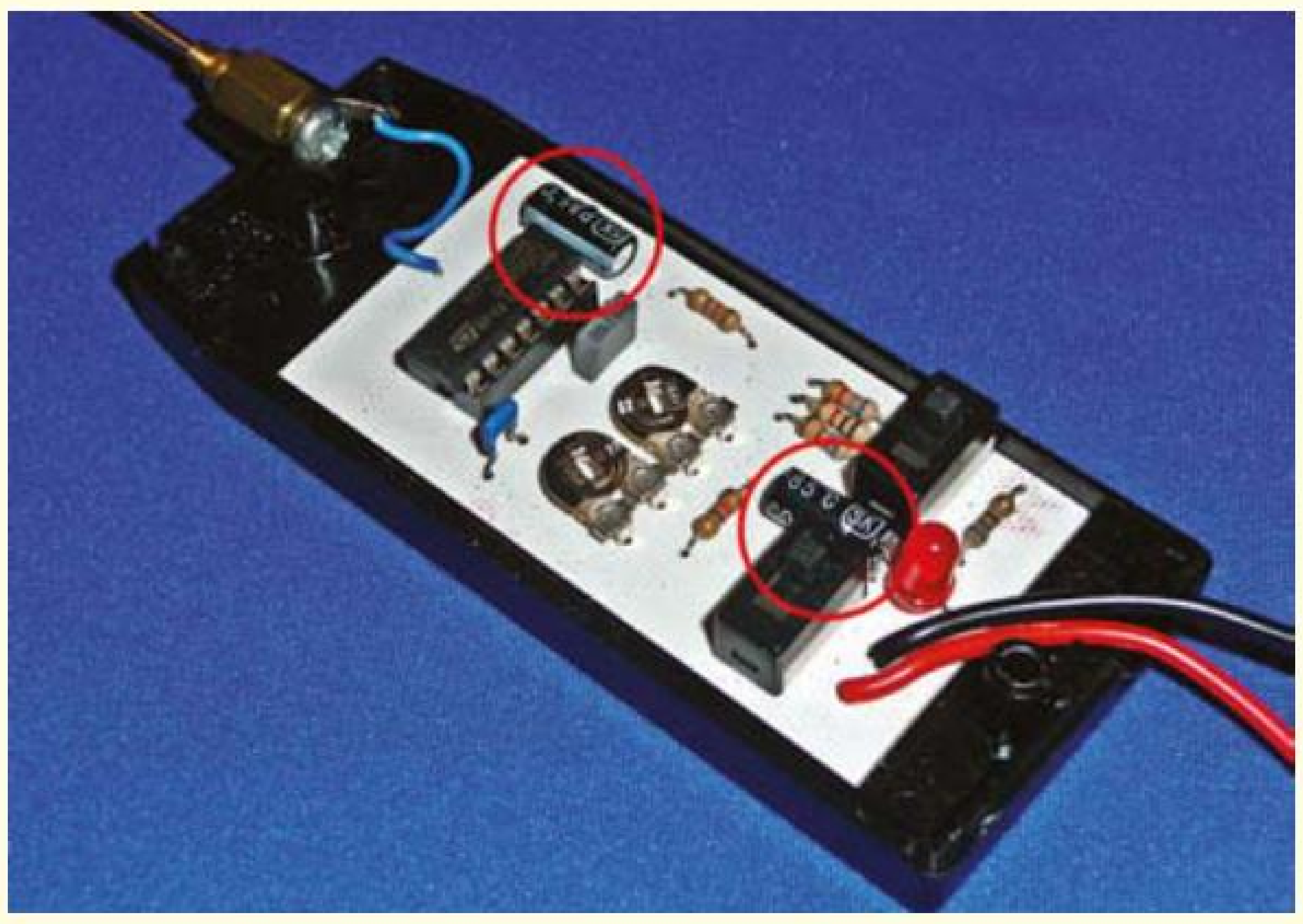


Fig.17. Bending the electrolytic capacitors in order to reduce overall height above the PCB

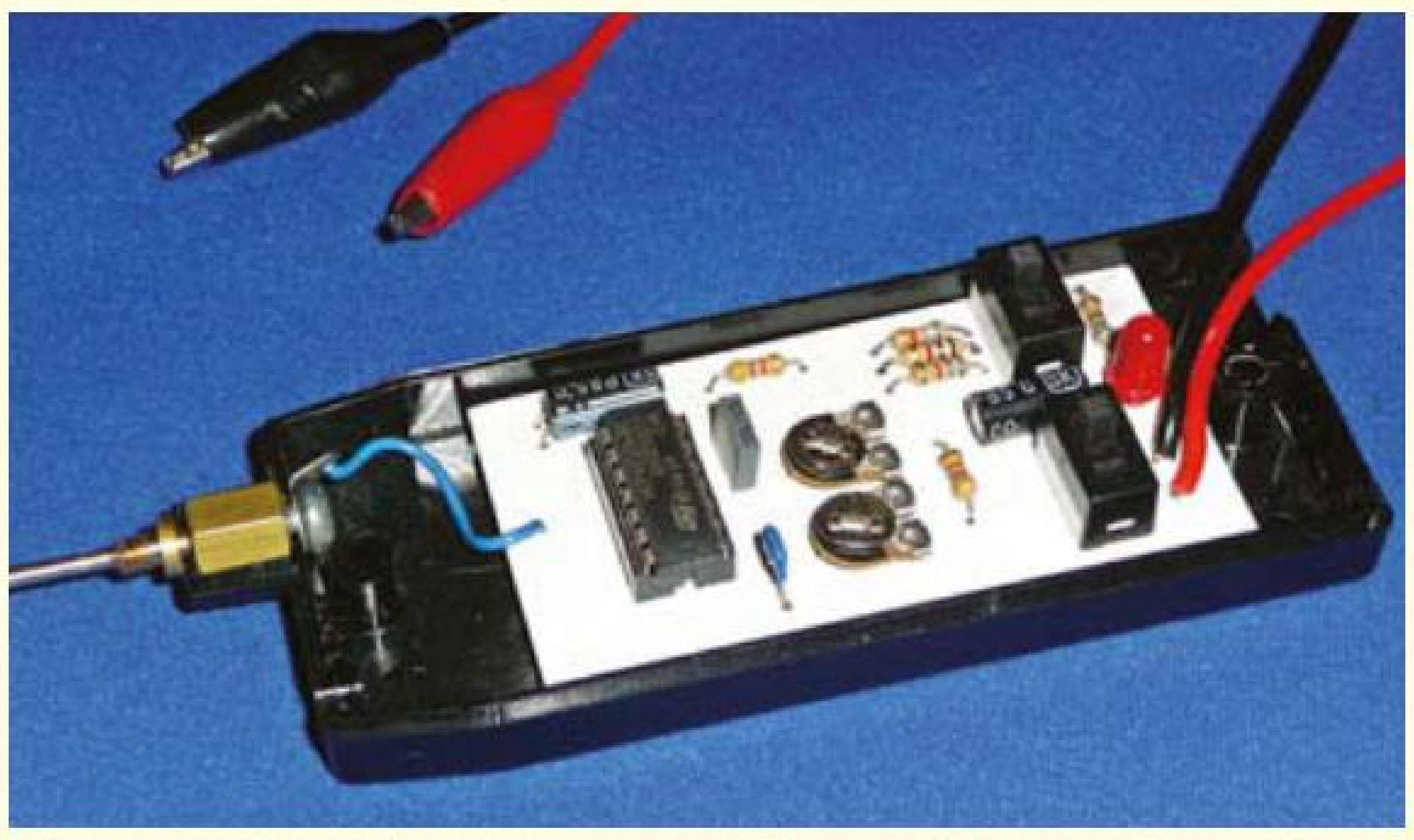


Fig.18. ***Signal Injector Probe,*** **without faceplate**

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

Next month
In next month's *Jump Start*, we shall be describing a *Simple Radio Receiver* that's ideal for use when you're away from home.

A note regarding Circuit Wizard *versions:*

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*

Raspberry Pi

Multimedia hub

Time for some Pi

Mike Hibbett

THE *Raspberry Pi* was originally conceived as a cheap educational computer for school children, but in the year since its release it has been put to many other interesting uses. It's no surprise that computer hobbyists have taken to its low cost and low power, but it has also found use as a standalone home media centre – a device capable of display pictures, videos and Internet-based media on a television.

It didn't take long for a media centre application to be release for the Pi, as an open source media centre already existed – XBMC, originally conceived for the Microsoft Xbox game console ten years earlier. The program was developed by hobbyists who released the software to the world with an open source licence, which means they released the source code to the application, and encouraged others to contribute to the work. Over the years, more than 60 developers have contributed, improving the design, the user interface and the number of embedded systems that XBMC can run on (including regular computers running the Windows or Linux operating system.) It was no great surprise that the Pi quickly joined the list of supported devices.

What is XBMC?

XBMC is an application that has been designed to run on a number of different computing platforms capable of video and audio output. The focus is on being able to play the user's digital media from a variety of sources such as memory stick, hard-disk, home network or the Internet, and be controlled by a variety of remotes such as keyboard and mouse, IR remote, Smartphone, or any other standard CEC controller.

You may be thinking that Microsoft Media Player does this already, and to a certain extent it does. Media Player, un-surprisingly, runs under Windows and is a proprietary program – hobbyists cannot extend it, improve it, or just tailor it to their own idea of how a media player should work. And Microsoft, naturally, have no intention of making Media Player run on the Raspberry Pi – their development direction is determined by profit, not by the interests of hobbyists and tinkerers.

Another significant difference between Media Player and XBMC is that XBMC has been designed for a 'Ten Foot User Interface' – the term coined for user interfaces that are designed to run on large screens (normally televisions) and viewed from the other side of a room, typically a home lounge. Menus contain big icons, large fonts and simple navigation, with the expectation that navigation is performed with a basic IR remote (although text can also be entered from a keyboard, if you have one connected).

The user interface is graphical and transitions from one display to the next are done in a smooth, gentle manner – not the fast, aggressive 'flick' that we expect from office applications, where the focus is on speed and efficiency, not relaxation and comfort. XBMC carries this off rather well. The user interface is attractive and easy to use, both with a standard IR remote and with a wireless keyboard (which we purchased from Maplin for £10; a great investment).

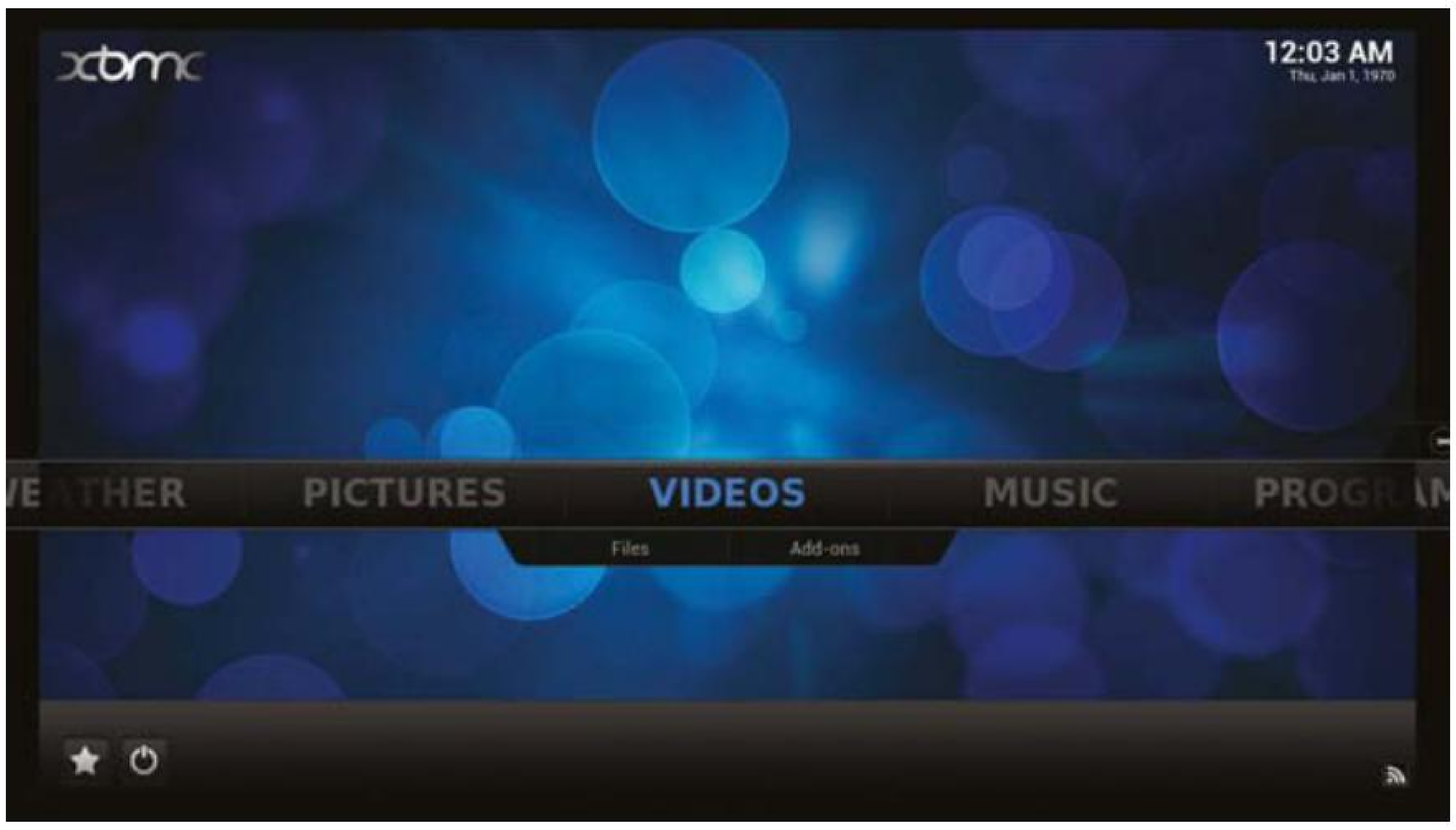


Fig.1. A typical XBMC startup display

XBMC is an application, not a complete embedded system. So, for the Raspberry Pi in particular, we have to look to other open source projects that have focused on creating a complete operating system + XBMC system, and for us, there are currently three main players: raspbmc, OpenELEC and Xbian.

From a user's perspective, there is very little to choose between them. In our experiments with all three, OpenELEC was the easiest to install (it recognised our Wi-Fi dongle, which the others didn't) and so we will discuss using OpenELEC in this article. raspbmc is more difficult to setup initially (it required a wired Ethernet connection for first boot, and I didn't have a 40-foot cable to connect the router to my television in another room) but it does provide support for homemade IR remote controllers out-of-the-box, which is something we are interested in. We will take a look at that in the next article.

These are very active projects, so a feature that is missing at the time of writing this article may well have been added by the time you read this. That is one of the benefits of open source projects; they are constantly being improved, and if the original author looses interest, someone else will pick it up and continue with it.

Features – so what does XBMC actually provide?

It has four categories of features, selected from the start-up menu shown in Fig.1.

Weather – displays the weather forecast in your area (or anywhere else, should you choose to select another location)

Photos – browse your collection of photographs

Video – Select and then play a video, in any one of many file formats. The usual pause, rewind and fast forward features are provided.

Programs – run a program specifically designed to operate within XBMC. There are hundreds of programs available, all for free, written by hobbyists and some commercial companies. There are games, web content viewers and programs that enable the viewing of YouTube and BBC iPlayer content, to name a few. The programs all operate with the XBMC user interface style, so they are easy to use from the comfort of your armchair.

XBMC also provides ‘profiles’, essentially different user accounts that enable you to restrict access to certain content. Very useful if you have young children, and not all of your media (or Internet access in general) is appropriate for younger viewers.

Add-ons

XBMC provides a well documented interface for people who wish to write their own add-ons, and there are many hundreds of people who have done so, making their creations available for free. The programming language of choice is Python, a powerful scripting language. It looks like quite a fun environment in which to write programs, but we have not yet had the chance to try making our own content. There is, un-surprisingly, a very active on-line community that has built up around the creation of add-ons for XBMC, so if you fancy trying it out, there is plenty of help available.

Installation

Let’s walk through the process of installing XBMC. We will need three pieces of software:

- The OpenELEC ‘image’ file for the Pi’s SDMedia card
- SDFormatter, a program for formatting SDMedia cards
- Win32DiskImager, a program for transferring disk image files to SDMedia cards.

The OpenELEC image can be downloaded from:

http://openelec.thestateofme.com/

Download the most recent zip file. Once downloaded, open it and save the .img file to your Desktop.

SD Formatter can be downloaded from:

https://www.sdcard.org/downloads/formatter_3/eula_windows/

This is a commercial program that is made freely available. Click on ‘I agree’ to accept the usual licence conditions, and once the zip file has downloaded, open it and run the setup.exe program inside it. A series of dialogs will guide you through the process of installing the program. SDFormatter is a disk format program that is designed specifically for SDMedia cards. Writing a Linux boot image to an SDMedia card changes the structure of the card to such an extent that Windows will not properly recognise it; SDFormatter understands this, and can restore the cards original format.

Win32DiskImager can be downloaded from its project page on the sourceforge website at:

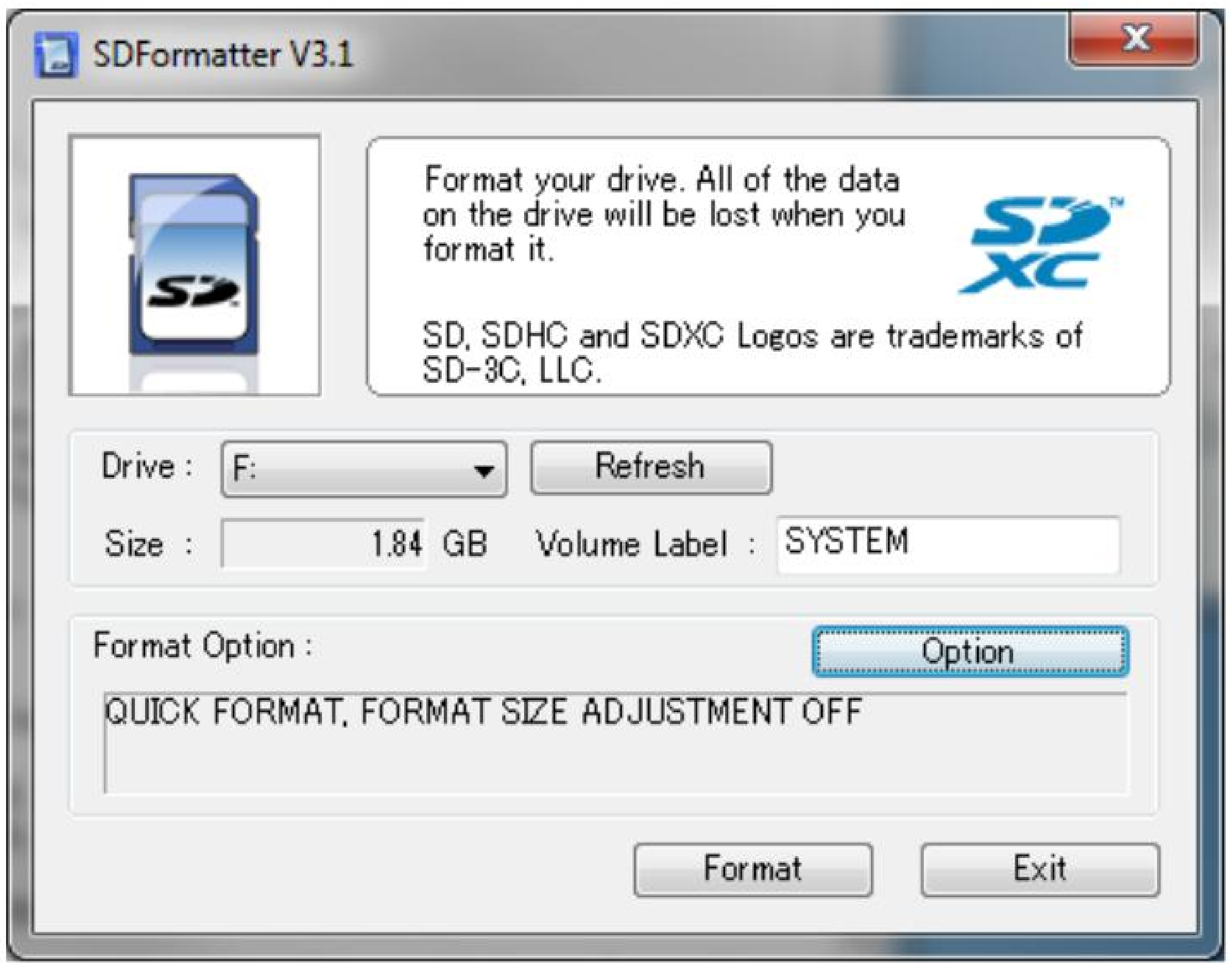
http://sourceforge.net/projects/win32diskimager/files/latest/download

Thefile is a zip archive; once downloaded, open the zip file and extract the contents to a subdirectory on your desktop.

Now we have all the tools, let’s go ahead and install OpenELEC on the card.

Start the SDFormatter application.

Ensure that the SDMedia card is select (see Fig. 2) and click on **Format**



Format your drive. All of the data on the drive will be lost when you format it.

SD, SDHC and SDXC Logos are trademarks of SD-3C, LLC.

Drive : F:

Size : 1.84 GB

Volume Label : SYSTEM

Format Option :

QUICK FORMAT, FORMAT SIZE ADJUSTMENT OFF

Fig.2. Formatting the SDMedia Card

When the format has completed (it should be only a few seconds) close the application. Now run the Win32DiskImager application. Under the ‘device’ drop down list (see Fig.3) select the SDMedia card. Then click on the folder icon to the left and select the .img file we just downloaded. Now click on the **write** button. Writing the contents to the card may take up to a minute.

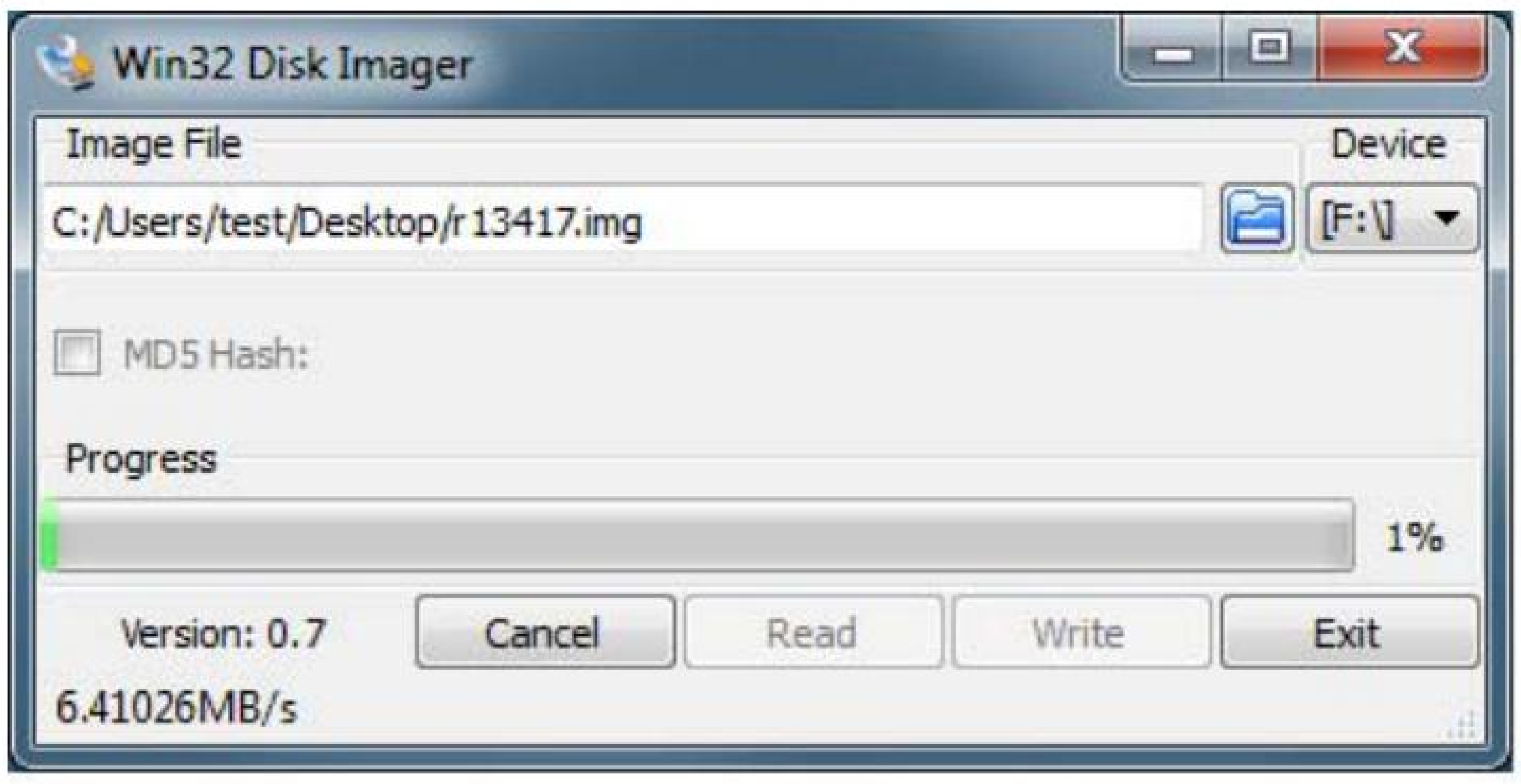


Image File: C:/Users/test/Desktop/r13417.img

Device: [F:\]

☐ MD5 Hash:

Progress 1%

Version: 0.7

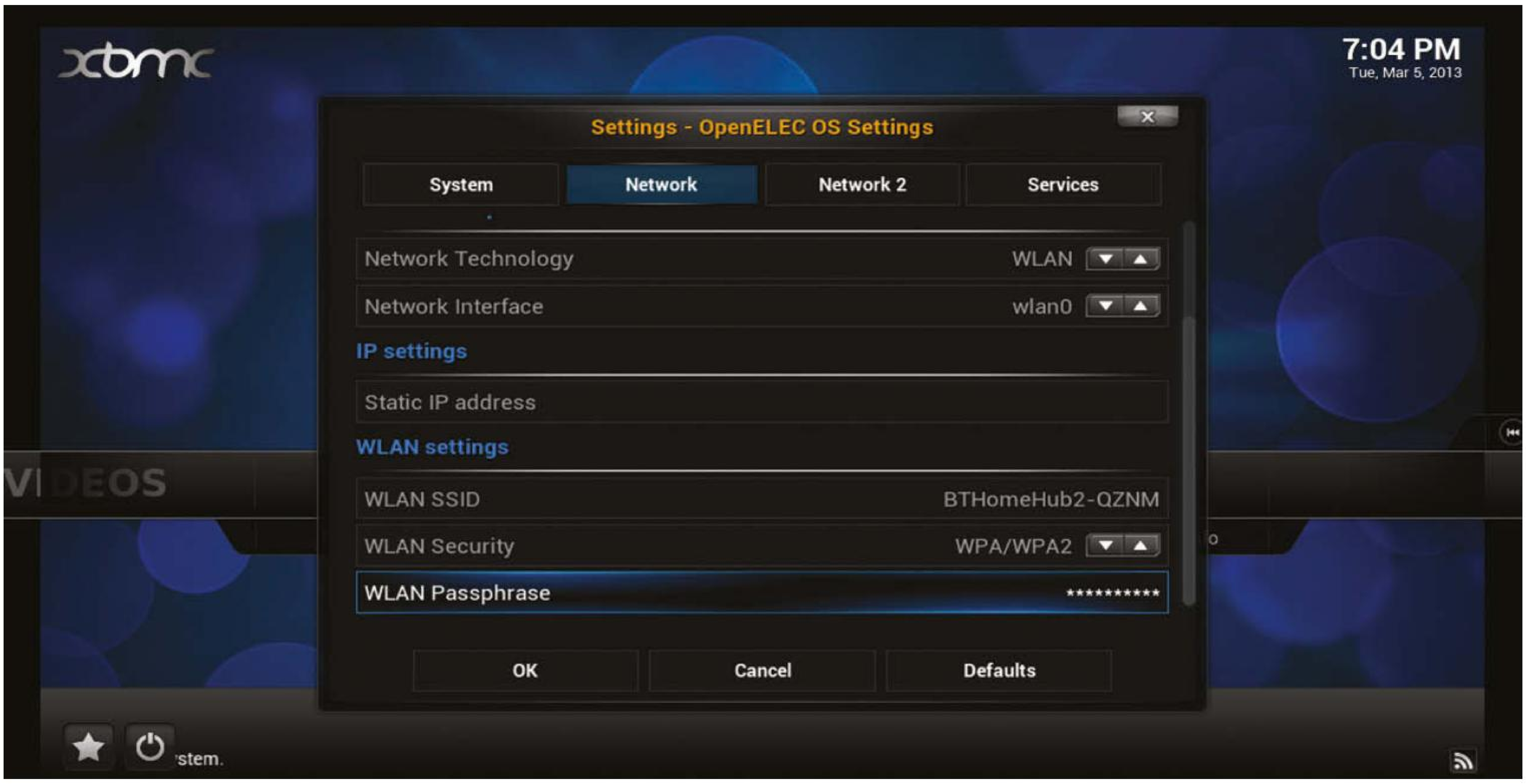
6.41026MB/s

Fig.3. Writing the image file

Once complete, close the program, and install the card in your Raspberry Pi. We assume you have already connected it to your television or HDMI monitor, and have switched to the correct HDMI input source for the Pi.

Configuring

Once the system has booted (which takes about 60s) you need to configure the name and password for the Wi-Fi access point you want to connect to. Using the cursor keys on your keyboard (this is where a cheap wireless keyboard comes in handy) highlight the SYSTEM option, press the ‘down’ arrow key and select the OpenELEC option. Move across to the ‘Network1’ tab, and select WLAN for the ‘Network Technology’ option, then WLan0 for the ‘Network Interface’. Scroll down to the ‘WLAN SSID’ option and enter the name of your access point, as shown in Fig. 4.



Settings - OpenELEC OS Settings

Network Technology WLAN
Network Interface wlan0

IP settings

Static IP address

WLAN settings

WLAN SSID BTHomeHub2-QZNM
WLAN Security WPA/WPA2
WLAN Passphrase **********

Fig.4. Configuring Wi-Fi

Scroll down again to enter the Security option (typically WPA/WPA2), then scroll down again and enter your access point's wireless key. Once entered, select OK, and then press the down arrow key again to select the power down option – you need to reboot for the settings to take effect.

Whenever powering down the Pi, always allow 10s or so for the Pi to complete writing its changes back to disk. There is no visual feedback about when it is safe to do so, and this is our only criticism of the system at present. At worst, you might corrupt the SDMedia card, requiring a re-install. As you do not save any media to the card, this is not a serious complaint.

So now you can attach your media and view your pictures or play your movies, or search through the range of add-ons available on the Internet. We used an 8GB Flash memory stick, as this could be connected directly to the Pi without a need for a USB Hub. A powered hub is desirable, however, if you want to attach a USB hard-disk or need to connect a keyboard, Wi-Fi interface and media device simultaneously.

For a comparable commercial product, the Apple TV springs to mind. A Media Player based on the Raspberry Pi works out at half the price, but is considerably more flexible and upgradable (although XBMC has been ported to the Apple TV, so perhaps that's not quite true!)

In the next article we look at installing a homebrew IR receiver, and explore some of the add-ons available.

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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Driving LCDs for low power consumption

We move onto two new topics over the next two articles; how to hook up an LCD to our low-power processor circuit, and how to use the real-time clock module within our PIC processor to reduce current consumption even further.

Hooking up an LCD may seem like a subject well covered, but we are looking at running our system at the lowest possible power consumption, and this introduces a few new tricks that will not have been covered before.

You may have noticed a theme developing here – minimising the power consumption. It's a niche area for hobbyist applications, but a useful one, and differentiates what we are doing from the Arduinos and Pies of this world (if 'Pies' is the plural of Pi!) which are powerful, but cannot be put into a very low power mode. While not relevant if you are recording video or doing lots of processing, there are still plenty of applications that only require a tiny bit of processor power periodically, and these really could benefit from a processor running for just a few tens of microamps.

Adding an LCD

We'll approach the LCD hook-up in two steps – the trivial implementation, so we can see what the current consumption is, and then the low-power version.

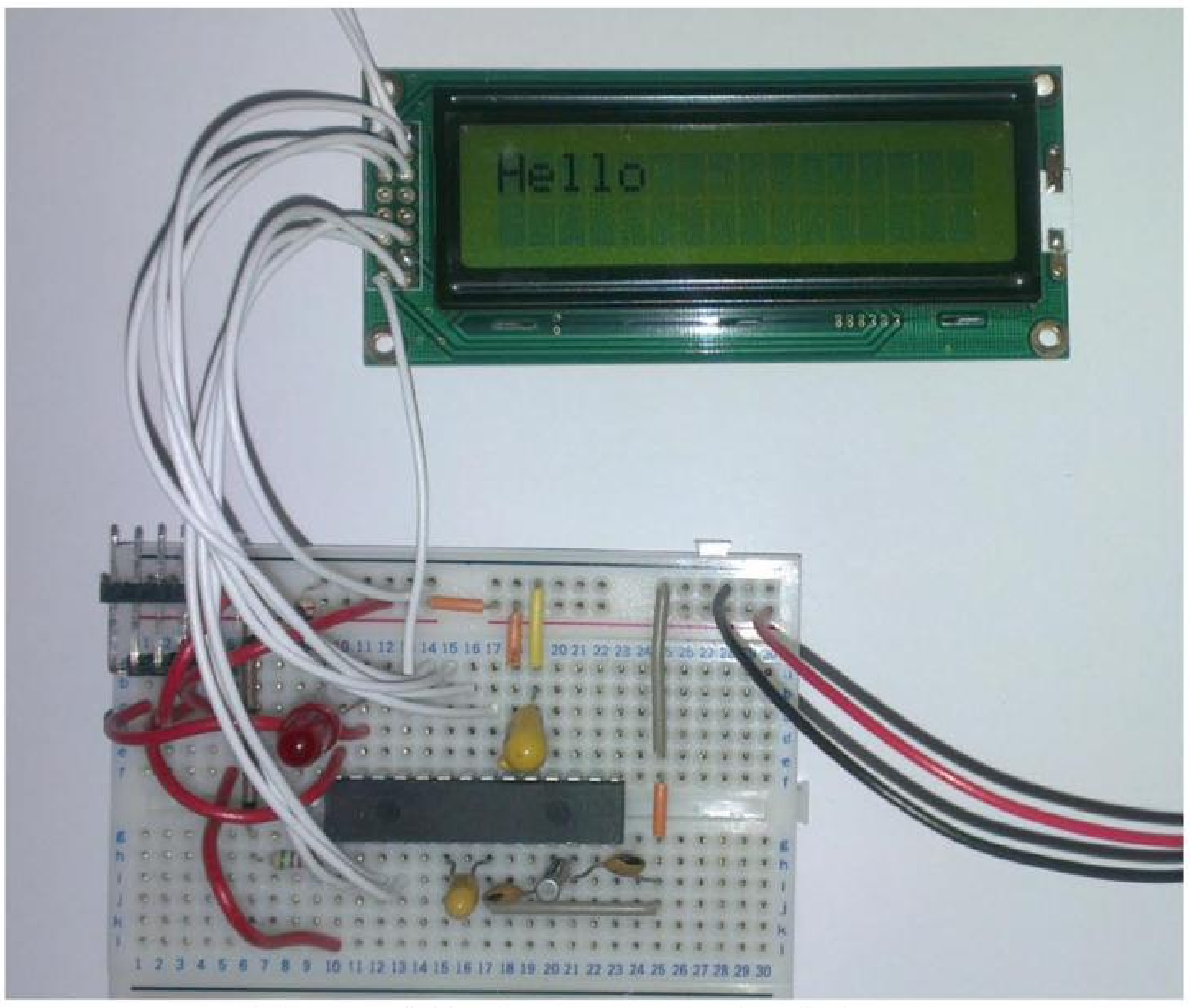


Photo of the low power circuit in use

We are re-using the 3V LCD module that was used with the Raspberry Pi article recently. Naturally, if we are trying to run at minimum power, it's important to use low-voltage devices wherever possible. Using a 5V module will require a 3V-to-5V converter, additional components to interface to the 3V processor and draw more power. There are plenty of low-voltage LCDs available on the market, so it's not difficult to find a suitable part.

The circuit is shown in Fig.1. In this design we won't connect the backlight up; the LCD we chose for the Pi article requires 5V for the electroluminescent backlight, and we dont have a 5V source. If you need a backlight then use an LCD with an LED backlight, and drive it via an *NPN* transistor under control of the PIC. Or alternatively, use a torch! A backlight will draw many tens of milliamps and will be a significant drain on a battery. There's nothing wrong with having a backlight, but if you have one, keep it under tight software control – and turn it off as soon as it isn't needed (with an automatic timeout to be certain.)

To connect the LCD control signals to the PIC we have to change our existing software slightly first.

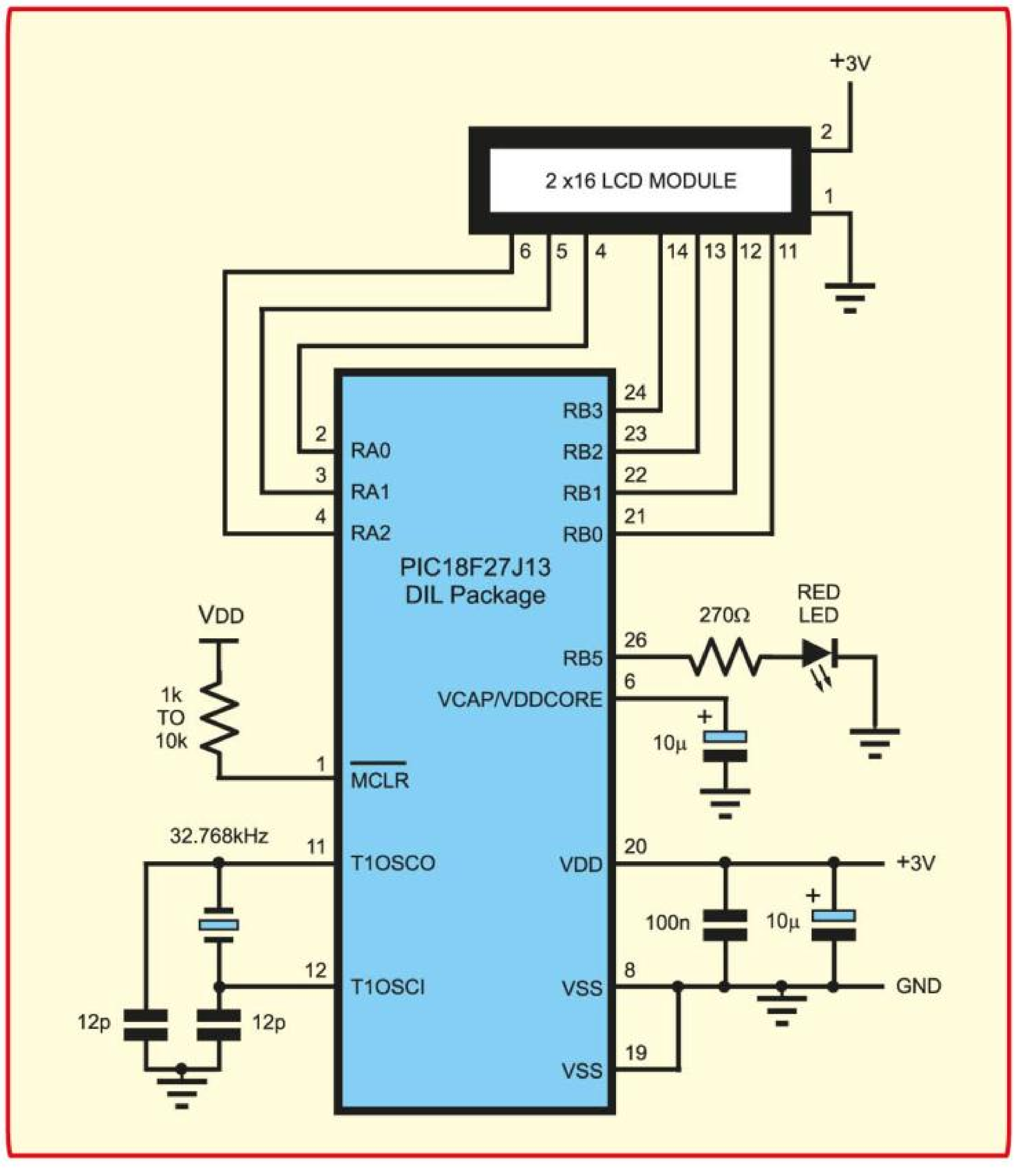


Fig.1. Initial circuit

Control signals

The LCD uses four wires for a 'nibble' databus and three wires for control (Enable, Select & Read/Write.) The software will be simplified (and a tiny bit faster) if the databus can be mapped to the four lowest bits of an I/O port, and PORTB is the easiest port to do this on. The three control wires will be placed on the lower three pins of PORTA. We avoid using the top two bits of PORTB as these are used by the debugger interface, and it's always handy to keep the debugger interface available, if possible.

The lower three bits of PORTA have alternate peripheral functions, but not ones that we might want to play with later.

We have to modify our software slightly as we rather lazily toggled all the bits of PORTB to flash the LED, rather than toggle the specific bit. The change is quite simple, replacing the line:

```
comf  LATB
```

with:

```
btg  LATB, 5
```

Analogue inputs

One of the usual PIC 'gotchas' comes into play now; we are hooking up the LCD signals to port pins that have analogue alternate functions. Microchip, in their wisdom, have decided that by default an analogue input is selected, so to turn these pins back into I/O port

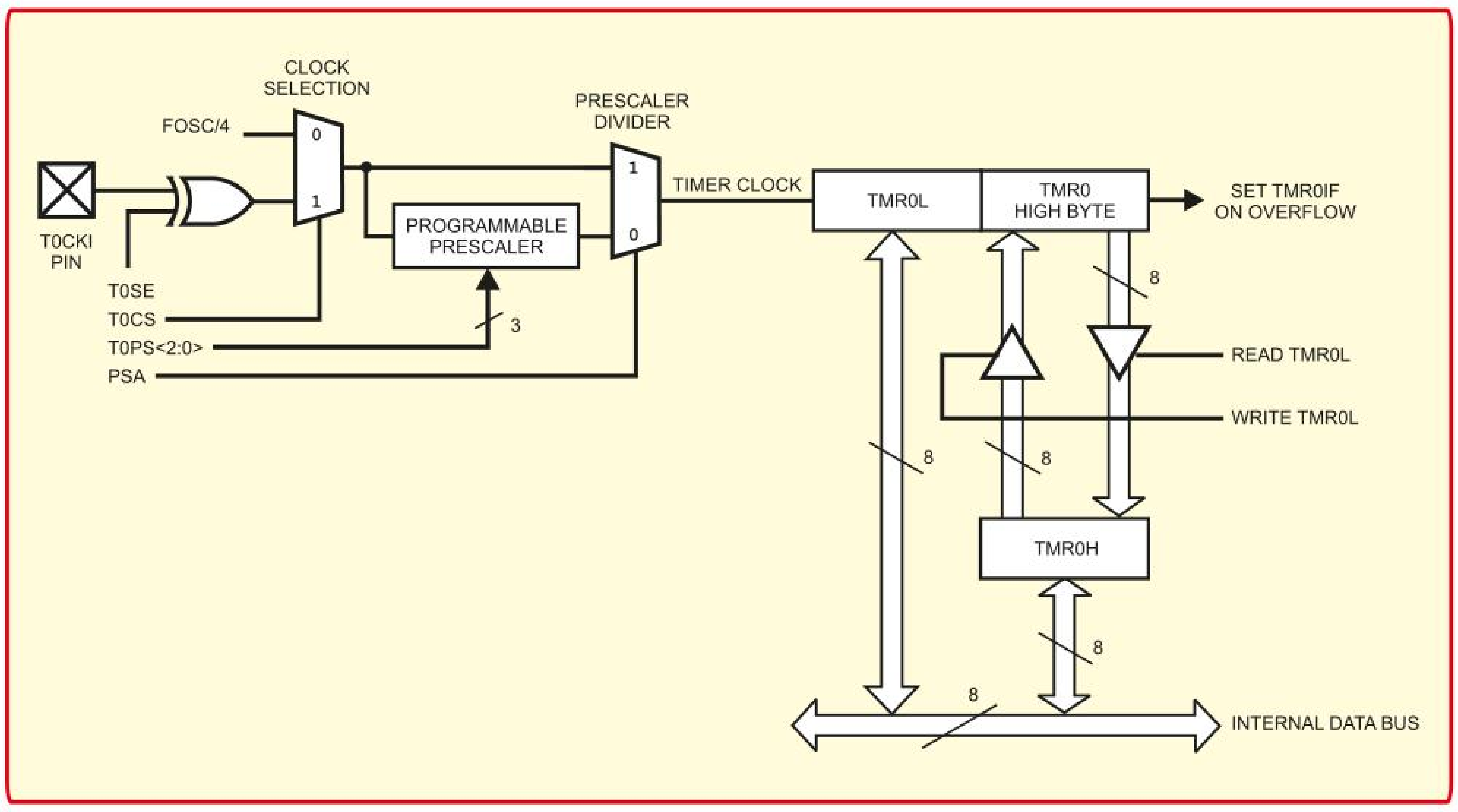


Fig.2. Timer 0 peripheral

pins you must write a '1' to the appropriate ANCON register. We do this with a short bit of initialisation code at the beginning of the program:

```
movlw  0x07
movwf  ANCON0
movlw  0x17
movwf  ANCON1
```

The datasheet for this display reveals that the display conforms to the standard LCD interface, so there is nothing interesting about how we drive the display. We simply re-used the 'C' code for the Raspberry Pi article as an example to help us write the PIC assembly language code, producing some simple routines to initialise and write to the display. The source code for this is available, as usual, from the magazine website under this month's section.

Translating the code is straightforward as there is nothing complicated about driving an LCD, and the subject has been covered many, many times so there are plenty of examples on the Internet. The most difficult task is working out how to provide the various delays (through the routine called **usleep** in our code.) There are different delay times required for operations such as power-on, display initialisation as well as very short delays while toggling control lines. These delays range from 80ms down to 2µs. They do not need to be very accurate, so long as they are slightly longer rather than shorter.

Delay routine

The 'quick and dirty' approach is to use a series of code loops, one inside another, and tweak the loops until the desired delay time is achieved. This can be easy to set up if you have an oscilloscope but very difficult if not, and quite wasteful of code and data space. A far better approach is to use a timer.

Our PIC processor is equipped with eight timers, so we are hardly short of resources. Our main requirement is that we want the timer to be able to count to 80ms, while also being able to delay for only a few microseconds. To cover this range of values we are going to need a 'wide' timer – at least 16 bits rather than 8. To see why, think about the range of values an 8 bit timer can hold – 256 values in the range 0 to 255. If our maximum delay time is 80ms (or 80,000µs) then dividing that maximum delay by 256 will give the smallest delay possible – 312µs. That is too 'coarse' a delay time given that we will be looking for delay times of 200µs, 100µs and 2µs.

A 16-bit timer on the other hand can hold 65536 values; dividing the maximum delay time required by this gives a minimum delay time of 1.2µs – close enough for our purposes.

So a 16 bit timer can handle the range of values that we want; the next question is, can we find a timer whose input clock can be configured to run at the speed required – we want each 'tick' of the timer to take about 1.2µs, or 833kHz. The timer modules do not have a fixed input clock, but include multiple input clock sources and divider circuits (called prescalers) to allow a range of input clock speeds. Starting with Timer0, the details of the peripheral are shown in Fig.2. The first multiplexer choses between the system clock (divided by 4, giving 12MHz) or an external clock signal on the T0CKI pin. We do not have an external clock source, so we will consider the 12MHz system clock. The prescaler can divide this clock down by multiples of 2, between 2 and 256. So we reach for the calculator to see if we can divide 12MHz down to something close to 833KHz.

Dividing 12MHz by 16 yields 750kHz; pretty close. But is it good enough? Can we derive the delay times we want?

To get the timer 'tick' rate, we simply divide 1 by the clock frequency in Hz. 1/750000 equals 1.33µs.

Delay times

So, we can now take each of the desired delay times and see if we can get close to them with a 1.33µs tick. As we are creating delays to allow the LCD to become ready, we take the cautious approach of looking for the closest *higher* value.

Desired value	Tick count	Actual delay
2µs	2	2.66µs
100µs	75	100µs
200µs	150	200µs
3ms	2250	3ms
8ms	6000	8ms
80ms	60000	80ms

Well, that's a welcome surprise – Timer0 fits the bill almost perfectly. The 2µs delay might be off by 30%, but is perfectly suitable for our purposes.

So now we have the timer source and configuration for our delay routine. Timer0, in 16-bit mode, clock source FOSC/4; and the prescaler set to 'divide by 16'.

Finally, how do we load the timer with our delay values and use the timer?

As a counter, the timer increments the contents of the 16-bit register TMR0 on every tick. When the timer registers 'rolls' from 65535 to 0, the bit TMR0IF is set. Although this is an interrupt signal we will not enable interrupts on Timer0, but instead, simply poll the TMR0IF flag in our software. We load the TMR0 register with the value **65536 – 'tick count'** to gain the required delay. The code for this can be found in the **usleep** routine. Note that each time we call this routine the timer is 'set up' from scratch. This initialisation code, which really only needs to be called once on power up, is very quick and so will not affect our delay times. It's left here to keep the code for the delay routine all in a single place – which will make maintaining the software easier in the future.

Control of the LCD introduces three new routines to our program: **LCDInit**, **setPos** and **writeLCD**. **LCDInit** configures the display from power up, setting the control pins to their default states (low) after sending some initial configuration to the display. This routine needs to be sent once only following power up.

The **setPos** routine is used to set the next location for a character write to the display. **writeLCD** will place a character on the LCD at the position specified by **setPos**. It will then move the write position to the right by one. Our initial test program wrote the word 'Hello' to the display before entering lower power mode. The code to do that is:

```
   ; write something to the display
   clrf          LCDCol
   clrf          LCDLine
   call          setPos
   movlw         'H'
   call          writeLCD
   movlw         'e'
   call          writeLCD
   movlw         'l'
   call          writeLCD
   movlw         'l'
   call          writeLCD
   movlw         'o'
   call          writeLCD

loop:
   sleep
   goto          loop
```

Current consumption

So how does this affect our current consumption? Remember that before we added the LCD, the current consumption was averaging (as far as we could tell from our DVM) at 50µA from 3.0V?

It's up to 1.06mA, pulsing to 1.1mA. So let's put that in perspective. If we are using two AA NiMH batteries with a capacity of 2.3Ah, our circuit will run for 2090 hours, or 87 days. Sounds good, but our circuit without an LCD would have run for five *years*, so we have lost all of our advantages. What can we do?

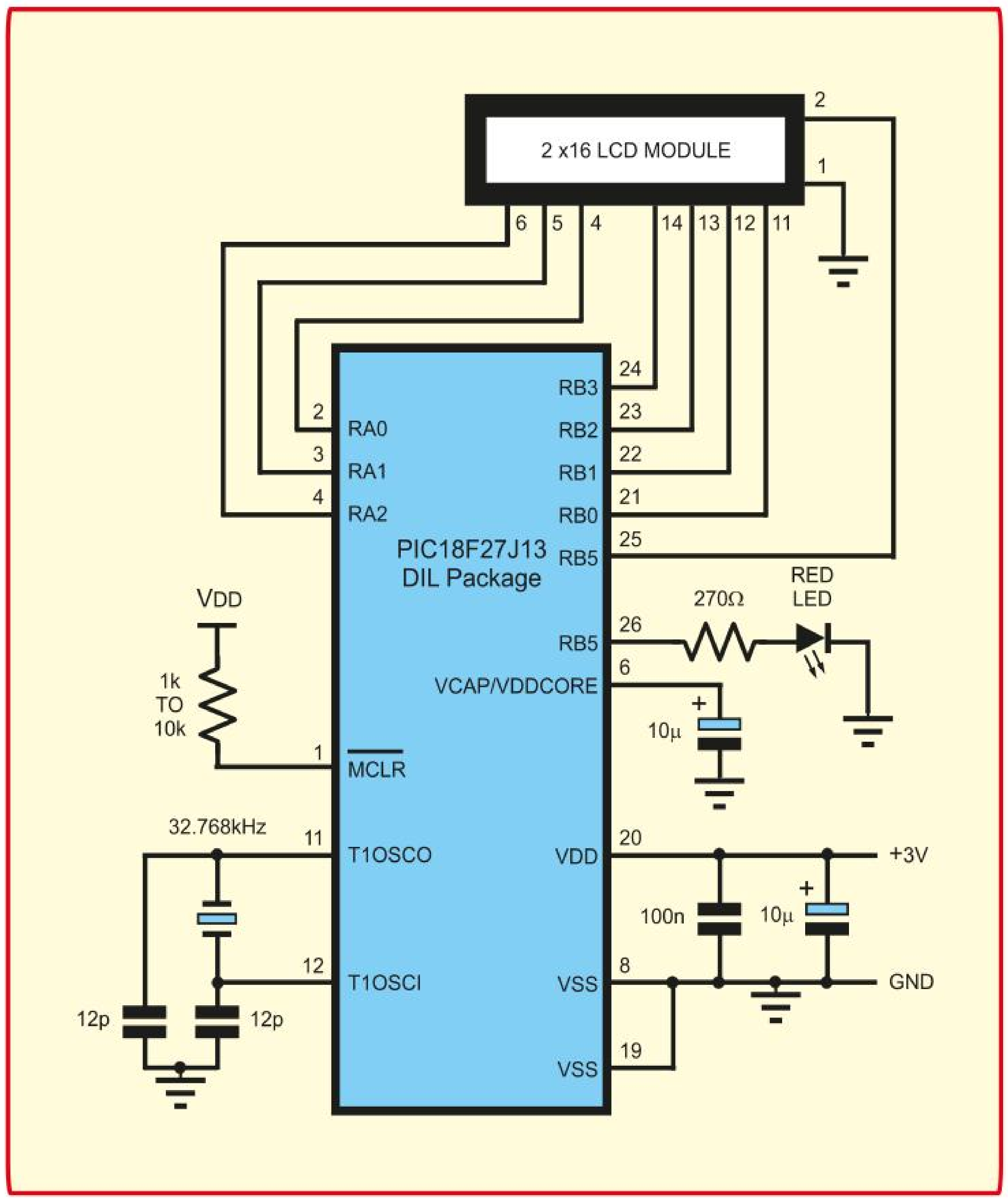
In many applications it's not necessary to keep a display on all the time; you can wait for a keypress before turning it on. Once the interaction with the user is over, the display can be turned off.

So let's see what this does to our current consumption. As the display only draws a millamp, we can drive the power pin directly from a high-power port pin – PORTB bit 4 is a good candidate. The revised circuit, such as it is, is shown in Fig.3.

Our second application extends the first by driving the PORTB bit 4 high, powering the LCD for ten seconds before turning the display off. This gives us the opportunity to find out what the current consumption is like when the display is turned off under program control.

The updated software is included in the download for this month's article. There is very little difference; we just set port pin RB4 high on startup, and then turn it off ten seconds later. Measuring the current consumption again, when the LCD is turned off, we see consumption falls back to 50µA.

That's a good result, and hardly surprising – all the signals to the LCD have been dropped to 0V, so there is no possibility of power leaking through any of the inputs. It is important to keep all the LCD signals low, as any voltage applied to an input pin will leak though to the main power input. This means that the signals driving the LCD cannot be 'shared' with any other devices. It's the kind of compromise we have to take when designing low-power circuits.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2
1
6
5
4
14
13
12
11
PIC18F27J13
DIL Package
RA0
RA1
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RB3
RB2
RB1
RB0
RB5
RB5
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T1OSCI
VDD
VSS
VSS
2
3
4
24
23
22
21
25
26
6
1
11
12
20
8
19
VDD
1k
TO
10k
270Ω
RED
LED
10µ
32.768kHz
12p
12p
100n
10µ
+3V
GND

Fig.3. Low-power circuit

Next month

Next month we look at how the real-time clock peripheral can reduce our current consumption even further.

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FEATURES • Jump Start – Spooky Circuits • Techno Talk • Interface • Circuit Surgery • Max's Cool Beans • Net Work

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M05/13

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

LTspice and op amp bandwidth

LAST month, we discussed a question about op amp bandwidth posted on *EPE Chat Zone* by **bowden_p**

> *I wish to put a 200kHz sawtooth waveform through several stages of op amp processing with reasonable fidelity. The incoming amplitude is up to about 0.5V p-p at about 3:1 rise/fall ratio, and the op amps then apply up to ×3 gain. What op amp gain-bandwidth product (GBP) would be needed for this task?*
>
> *I believe a sawtooth waveform has both even and odd harmonics, so if say the 6th harmonic is to be passed without much loss, then 200kHz × 6 × 3 is the signal bandwidth = 3.6MHz. The op amp open-loop gain required to pass this without much loss would then be, say a minimum of 10, so the overall GBP comes to 36MHz!*
>
> *(The op amps would have feedback applied to limit gain to the required ×3 or less.)*
>
> *1. Is this a good estimate of the GBP required?*
>
> *2. How does this relate to the unity-gain frequency quoted in data sheets?*
>
> *Is this true, or have I lost the plot somewhere?*
>
> *All comments welcome; my forte is not in analogue electronics, but I am trying to understand this area more.*

Frequency response

In reply, we looked at the relationship between op amp feedback and frequency response, op amp frequency compensation, and of course, the meaning of the term gain-bandwidth product (GBP). To repeat the basic answer to the main question: assuming that six harmonics is sufficient, as stated, the required bandwidth is 200kHz × 6, which is 1.2MHz. The stated gain is 3, so the implied GBP specification is 3.6MHz. However, when considering whether a given op amp is up to the job of handling a high frequency signal, there may be factors other than just frequency response to consider.

In particular there is slew rate, which should always be checked. Indeed, slew rate was an element in the *Chat Zone* discussion which resulted from **bowden_p**'s post. The thread also included discussion of a SPICE simulation of a circuit by *Chat Zone* regular contributor **741**. In response, **bowden_p** said that he would try LTspice for the first time.

As regular readers will know, we make quite frequent use of LTspice simulations in *Circuit Surgery*, but for brevity, we do not always provide full details of how the software was set up. However, this month we will provide some additional background for anyone, like **bowden_p**, who is new to SPICE.

We will look at how to simulate a circuit's frequency response using LTspice, and illustrate the concept of GBP using this. We will also show how to perform transient (time-based) simulation, and look at how these results relate to frequency response simulations. This will also show the effect of limited slew rate. Next month, we will look at slew rate in more detail.

SPICE it up

SPICE was developed in the early 1970s at the University of California, Berkeley. SPICE is now a *defacto* industrial standard for computer-aided analysis of analogue electronic circuits. There are many commercial versions of SPICE available, under a variety of names, some embedded in larger electronics design software applications.

SPICE was originally developed because ICs require complex, expensive fabrication processes and cannot be changed significantly once they have been manufactured. Using a simulator to analyse a circuit greatly increases the chance that an IC will work correctly the first time it is fabricated. Although SPICE was originally developed for IC design, there is no reason why you should not use it to simulate discrete components – in fact, many manufactures of devices such as op amps provide SPICE models of their products to facilitate accurate simulation.

Spice was originally an analogue circuit simulator, but modern versions allow logic gates and more complex digital functions to be included, allowing digital and mixed-signal (analogue and digital) circuits to be simulated. However, SPICE would not normally be used for large fully digital circuits. Some applications integrate SPICE with digital simulators in what is known as co-simulation.

Not only does SPICE simulate the behaviour of electronic circuits, but it also emulates, via a number of analysis options (or simulation commands), the equipment used in the laboratory, such as signal generators, multimeters, oscilloscopes, spectrum analysers and curve tracers. These different analyses provide different types of information about the circuit under investigation.

As already indicated, one well-known version of SPICE is LTspice (also known as SwitcherCAD IV) from Linear Technology (**www.linear.com**). LTspice is optimised for simulating switched-mode power supplies; however, it also does a fine job with 'ordinary' SPICE simulation tasks. Linear Technology produced the simulator because many other SPICE simulators struggled with switch-mode circuits due to the complexity of the waveforms involved.

Do note that LTspice is free from Linear Technology's website: **www.linear.com/designtools/software/**. There is a getting started guide for new users on the download page, and extensive help files built into the application. There are many LT enthusiasts online, including a few regular *EPE Chat Zone* contributors, so you can find helpful discussions and information.

As you might expect, LTspice, and other modern SPICE versions, allow you to draw schematics of the circuit you want to simulate on the screen (schematic capture). However, the first versions of SPICE predated modern graphical user interfaces by many years, so circuits were defined using text descriptions known as netlists.

Commands

The operations performed by the simulator were originally determined just by text commands placed in the input text file, along with the netlist. Nowadays, many functions can be set-up via dialog windows in an application's user interface. However, with LTspice it is sometimes necessary to write commands manually and place them on the schematic. The full netlist and set of text commands for an LTspice simulation can be seen by selecting 'SPICE Netlist' from the View menu.

In SPICE parlance, 'elements' are the components in a circuit, and 'nodes' are the wires, that is, the electrical connections between elements. All linked wiring is a single node, however complex the lines on the schematic may be. Individual segments of wire are not separately identified. All nodes are given names or numbers and will be named automatically by a schematic capture system if you do not do it yourself. You are advised to name any node which are you interested in observing in simulation, otherwise you have to find and remember what the simulator called it ('n000', 'n001' etc).

Node zero is a special case – the ground or earth node – the reference to which all other node voltages will be expressed. All SPICE circuits must include at least one ground node. If you fail to do this in LTSpice, you get a fatal error: 'This circuit does not have a conduction path to ground! Please flag a node as ground'.

Software models

In order to accurately simulate a device such as a transistor or op amp, the simulator needs to know a lot of information about the characteristics of that device. This information is held in models that are provided with the software or obtained separately. The models either consist of a set of equations (typical for transistors and diodes) or an equivalent circuit known as a macromodel (typical for op amps).

Equation-based models for devices such as transistors are typically generic and built into the simulator. The user supplies the correct numerical values for a specific device for all the parameters required in the equations (forward-current gain for a transistor). Macromodels are usually provided separately for specific components and already include their parameter values (open-loop gain for an op amp).

The LTspice download includes a set of models of Linear Technology devices, particularly op amps (over 200 of them) and regulators, but other 'standard' Spice models will work with it if you have them available. There are also models of several transistors and diodes from various manufacturers included.

Simulation

Having provided this very brief introduction to SPICE and LTspice we can take a look at simulation. The circuit in Fig.1 can be used in LTspice to compare the performance of two op amps, one of which is suitable for **bowden_p**'s application, and another which isn't. We will start with a frequency response analysis.

There are a few things to note about this schematic. We have labelled (named) some, but not all nodes. The labelled nodes are ones we want to look at in the simulations (In, OutF and OutS) and the supplies (Vp and Vn). The supplies are labelled so we can wire up the power connections to the op amps just by labelling them – we do not have to draw wires which might make the schematic more difficult to read. We have four ground symbols; remember there must be at least one.

The supplies are modelled with ideal voltage sources with a DC voltage set (right click to do this). The input signal is also modelled with an ideal voltage source. This time we right click and select 'Advanced', giving access to detailed configuration options. Because we are performing a frequency response we need to set the AC amplitude in the 'Small Signal AC analysis (AC)' section of the window. This should be a small value, here we have used 0.25mV.

To perform the frequency response simulation (AC analysis), select 'Edit Simulation Cmd' from the Simulate menu. Then select 'AC analysis'. Enter the details of what you require. We used a decade plot with 20 points per decade from 1kHz to 100MHz (entered as '100Meg'). The text simulation command generated by the dialog must be placed on the schematic, as shown in Fig.1 (.ac. dec 20 1000 100Meg).

To run the simulation, select Run from the Simulation menu. A graphing window will open, but will be blank at first. As we want to display two plots, right click select 'Add Plot Plane'. To add a graph (trace), right click one of the plot planes and select 'Add Trace'. In the dialog, click on V(outf) from the available data list and then add a divide symbol (/) to the 'Expression(s) to add:' box. Now click on V(in). The expression should be V(outf)/V(in), that is the gain of the faster op amp circuit. Repeat this process with the expression V(outs)/V(in) in the other plot plane. The result is shown in Fig.2. These plots do not include the phase, which is plotted by default – left click the right axis and select 'Don't plot phase.' to replicate this.

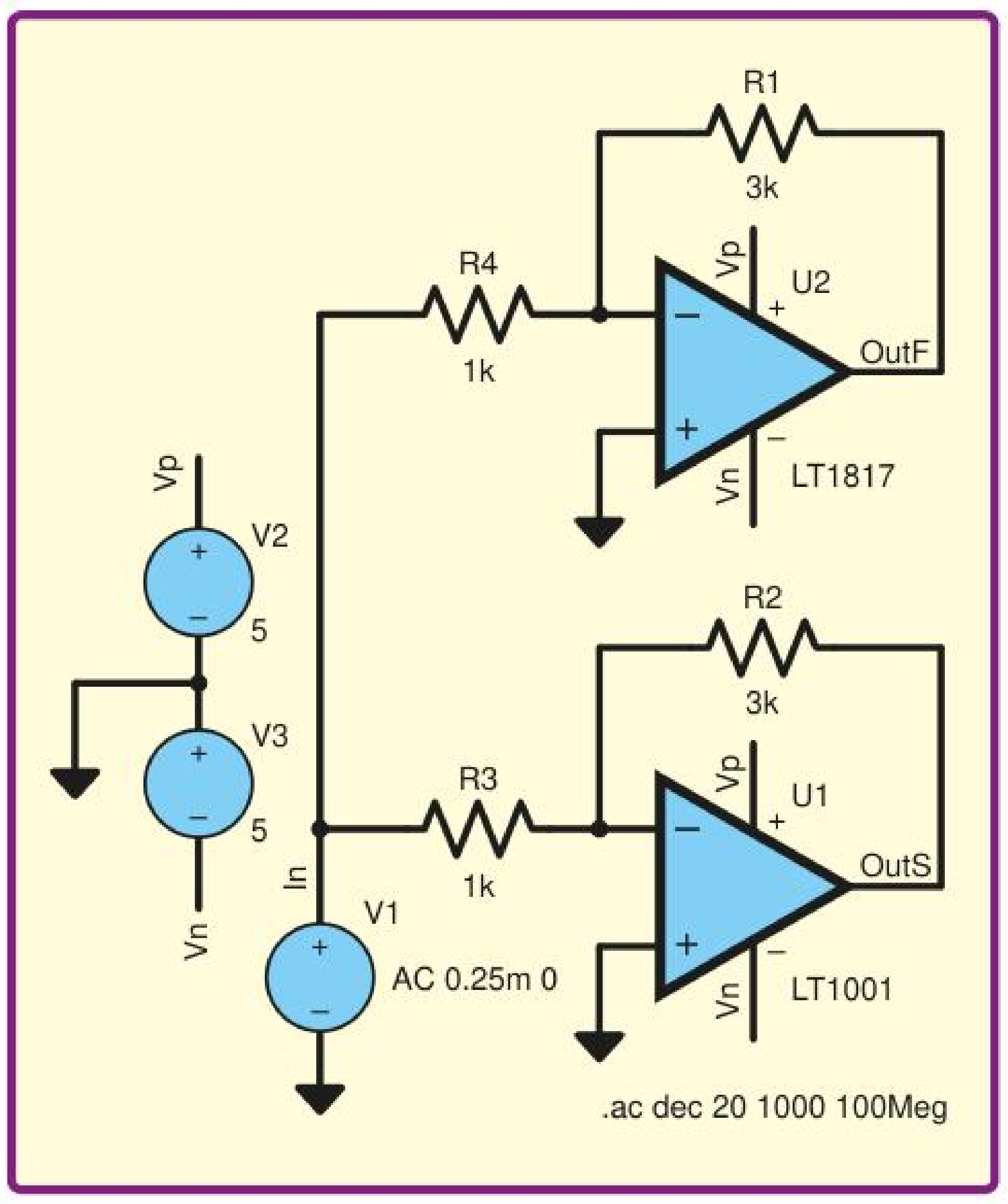


Fig.1. Circuit for LTspice simulation comparing a fast (LT1817) and slow (LT1001) op amp

Gain-bandwidth product

Last month's discussion concentrated on gain-bandwidth product (GBP) and the fact that it is often almost constant for op amp amplifiers; we can illustrate this by changing the circuit's gain to see the effect on bandwidth. For example, increase the gain by a factor of 10 by changing the 3kΩ feedback resistors in the circuit in Fig.1 to 30kΩ and resimulate – the results are as shown in Fig.3.

The LT1817 amplifier's bandwidth decreases from about 89MHz to about 8.9MHz, and the LT1001 amplifier's bandwidth decreases from about 270kHz to about 28kHz. In both cases, the tenfold gain increase results in a tenfold decrease in bandwidth – therefore, the GBP is more or less constant.

To make accurate measurements on the graphs you can use LTspice's cursors. To find the bandwidth (–3dB point) from the results just obtained, right-click

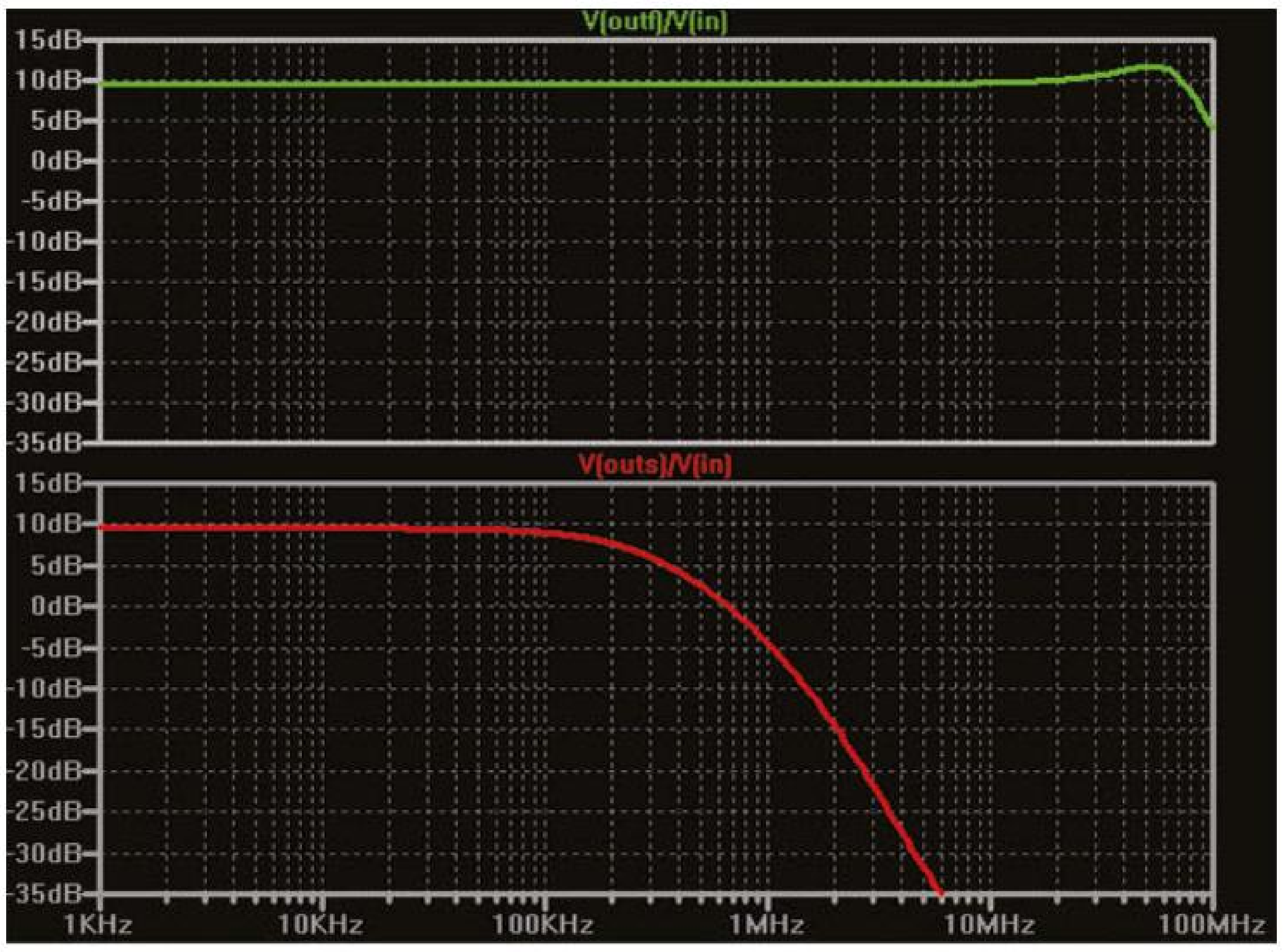


Fig.2. Frequency response analysis for the circuit in Fig.1

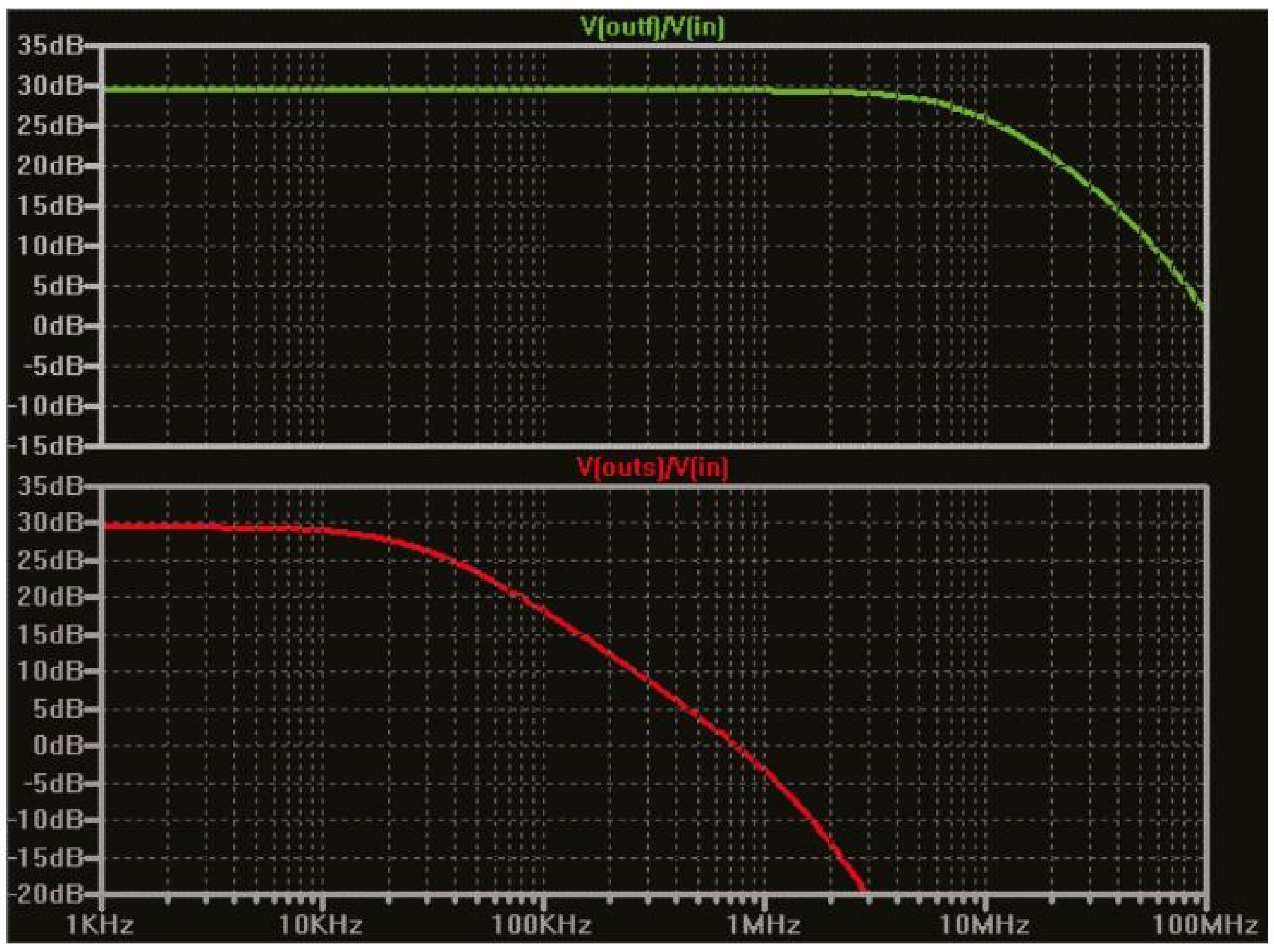


Fig.3. Frequency response analysis for the circuit in Fig.1 with the gain increased from 3 (9.5dB) to 30 (30dB). Note the reduction in bandwidth compared to Fig.2

on the node name/expression above the graph and set 'Attached Cursor' to '1st and 2nd'. A window showing measurements from the cursors will appear. Drag the first cursor to the lowest frequency and move the second until the magnitude (Mag) ratio (Cursor 2/Cursor 1) is as close as possible to –3. The cursor 2 frequency gives the bandwidth.

AC analysis

The AC analysis does not tell us much about what real signals in the circuit might be like. AC analysis is also called small-signal analysis because it uses very low amplitude sinewaves to ensure that the circuit does not distort the signal. This assumption simplifies the calculation required, allowing the simulation to be performed much faster. The simulator may have to find tens or hundreds of points to plot a frequency response. Performing a full simulation of the circuit's response to many cycles of a sinewave for each frequency point would take too long.

When SPICE performs an AC analysis, it starts by computing the DC operating point of the circuit; that is, the voltages and currents which occur when no input signal is present. Then all non-linear devices (such as diodes and transistors) are linearised at this operating point – the simulator determines simple 'straight line' equations to represent the response of each component to very small deviations from the 'no-signal' conditions. The simulator then uses these linear equations to directly calculate the circuit's response at the frequencies of interest.

Transient simulation

To see waveforms, we need to perform a transient simulation, and before we can run this we need to set up the input signal and configure the simulation command. Despite **bowden_p**'s requirement for a triangle wave amplifier, we will start by simulating a sinewave input signal. In fact, we will use a low amplitude signal similar to the one implied by the AC analysis (250µV peak). This can provide some useful insights.

To set up the signal source, right click on the V1 voltage source and select SINE under Functions and enter 0.25m in the Aplitude[V]: box and 200k in the Freq[Hz]: box. To set up a transient analysis simulation, choose 'Edit Simulation Cmd' from the Simulate menu, then select the Transient tab. Enter 250u in the 'Stop Time:' box (to set how long the simulation will run for). Click to place the command on the schematic. The results from running the simulation are shown in Fig.5. The input signal and the two amplifier outputs have been added to separate plot planes.

To facilitate comparison, the waveform display shown in Fig.5 was manually set up so that the two output signals are both on graphs with a range of 2V top-to-bottom and the time axes were synchronised (the default autoranging may give graphs with different scaling). Right click the graph to access display setup functions.

We can see that the two op amps produce amplified and undistorted sinewave outputs. The output from the LT1817 (V[outf]) is 180° out of phase, as would be expected from an inverting amplifier. The LT1001's output is somewhat shifted from this position because we are reaching the limit of its bandwidth.

Output

With a designed gain of 3, we would hope for an output of 1.5mV peak-to-peak from the 500µV peak-to-peak input. As with the frequency response graph, we can make accurate measurements on the waveforms by activating the cursors. We find that the output from the LT1817 has the expected amplitude, but has a significant offset of about –7.5mV.

The output from the LT1001 has an amplitude of 1.17mV peak-to-peak, indicating a gain of 2.34. This is reasonably close to the gain of 2.4 (7.6dB) at 200kHz indicated by the response in Fig.2 – the reduced gain at this frequency is expected due to the relatively small bandwidth of this circuit.

Unlike the LT1817, the LT1001's output does not suffer from significant offset, this is because it is a high-precision amplifier designed for accurate amplification at DC and low frequencies. On the contrary, the LT1817 is designed for high-frequency AC amplification and high-speed operation, and is clearly better in this respect. It should be obvious that it is important to choose the right op amp for the job in hand.

For our next simulation, we will keep to our input sinewave at 200kHz, but increase its amplitude by a factor of 100 to 500mV peak-to-peak – in line with **bowden_p**'s required triangle-wave amplitude. Resimulating, we obtain the results shown in Fig.5.

The simulation results shown in Fig.5 indicate the LT1817 is performing as expected. It is producing a sinewave output at the correct amplitude of 1.5V peak-to-peak due to the gain of 3V and the 500mV input. The far larger signal levels, in comparison with Fig.4, mean that any offset is not visible.

Distortion

However, there is a problem with the output from the LT1001. Its amplitude is about 528mV, which is a gain of less than 1.1, less than then the 2.34 obtained with the 500µV input at the same frequency. Linear amplifier gain should not change with signal amplitude (at a fixed frequency), but if it does, the result is distortion. This is visible in the waveform in Fig.5 – the output is not a sinewave, it is getting closer to a triangle. Unfortunately, it is not the triangle wave that **bowden_p** is after!

The distortion of the waveform seen in Fig.5 is due to the relatively low slew rate of the LT1001 in comparison with the LT1817. Again, this is to be expected because the LT1001, unlike the LT1817, is not designed for handling fast signal changes. We will look at slew rate and its relationship to bandwidth next month and also simulate the circuit with **bowden_p**'s triangle wave signal.

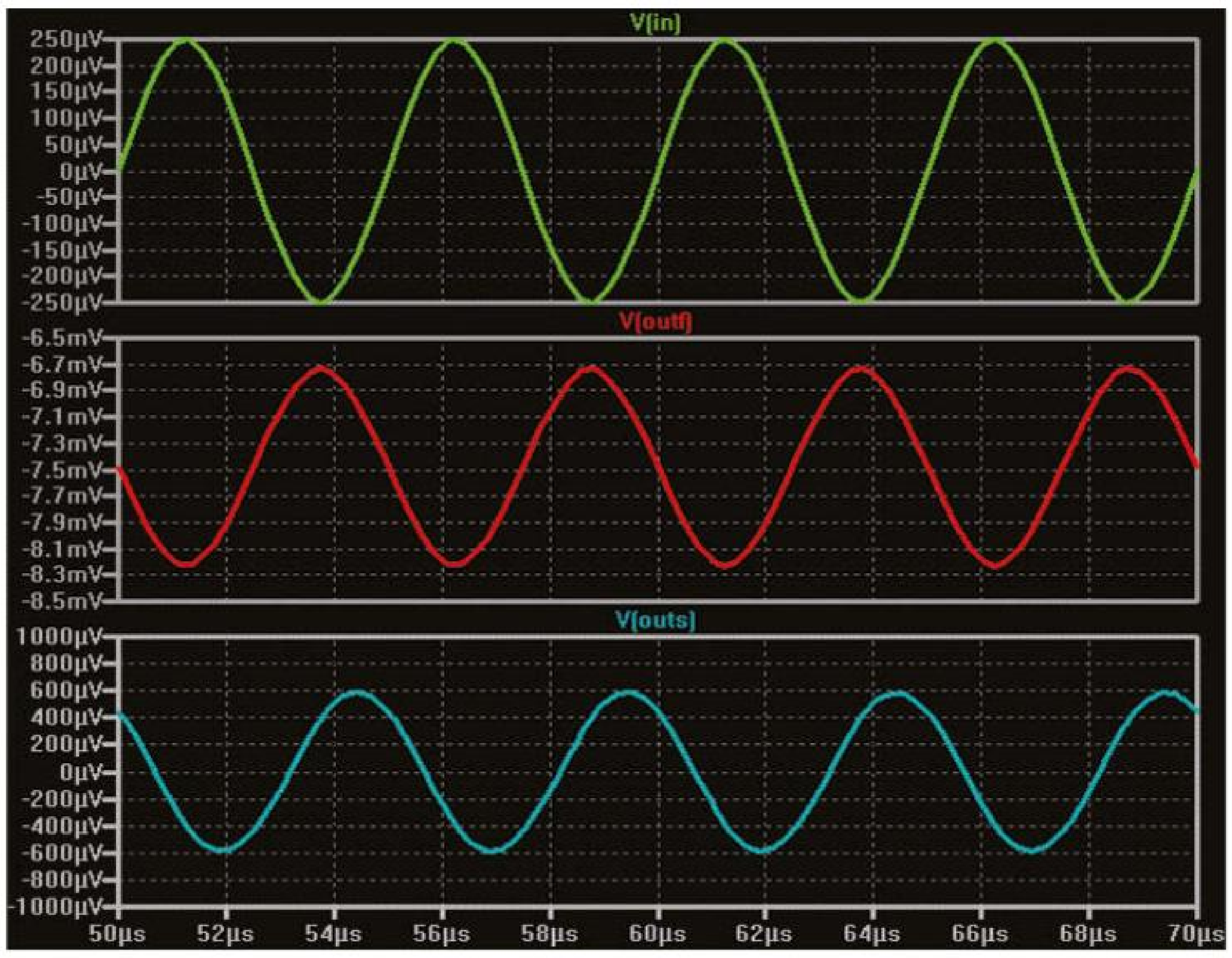


Fig.4. Transient simulation of the circuit in Fig.1 with a low amplitude 200kHz sinewave input

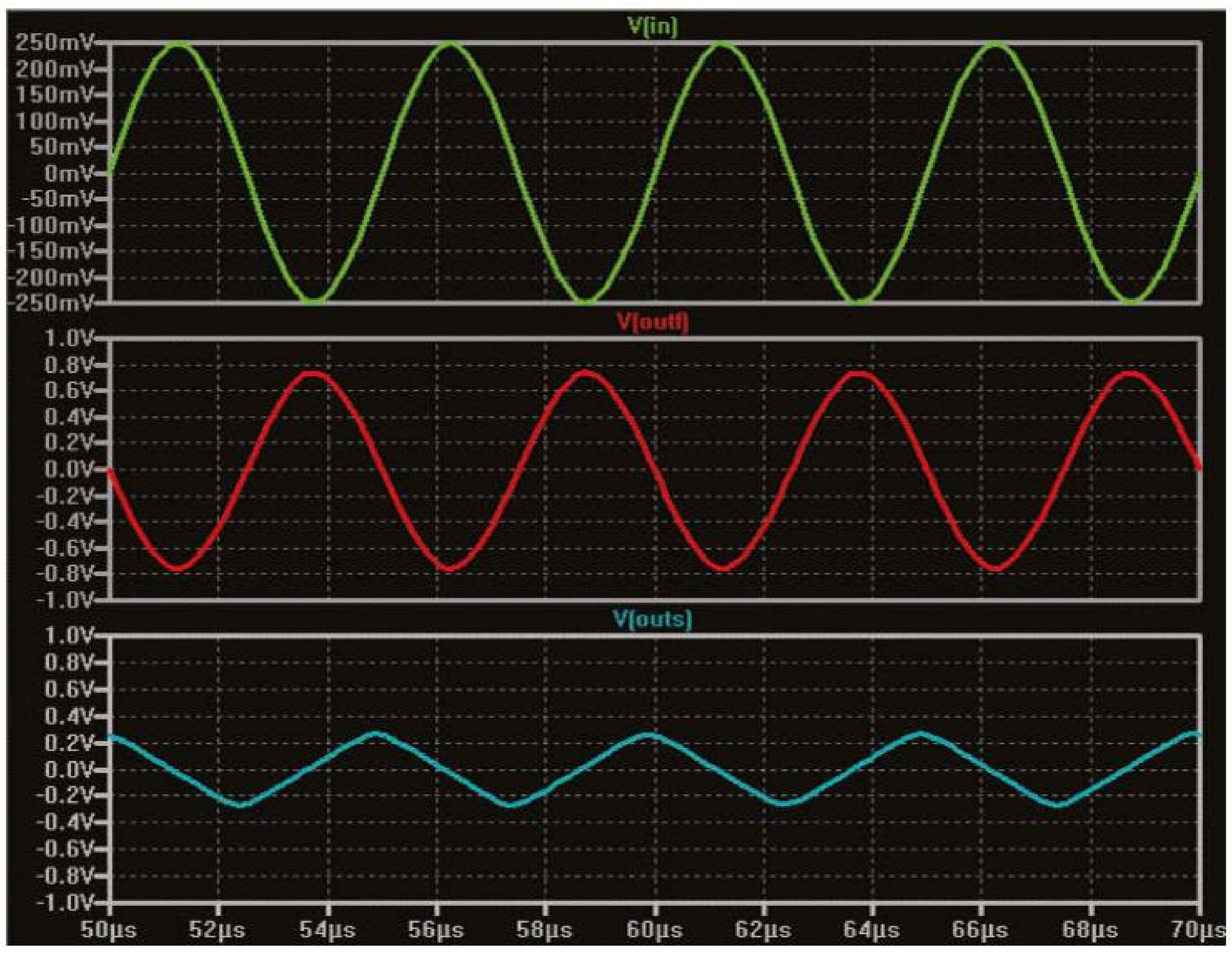


Fig.5. Transient simulation of the circuit in Fig.1 with a larger amplitude 200kHz sinewave input

Max's Cool Beans

By Max The Magnificent

When I was a young lad, I used to be a devoted reader of hobbyist electronics magazines like *Practical Electronics* (which evolved into the *EPE* we know and love today) and *Practical Wireless*. When it came close to the time for the next issue, my first stop on the way home from high school was the newsagents at the bottom of our road.

I didn't have much money (or skill) at that time, so I loved simple (and affordable) projects. As soon as a new issue had arrived, I would hop on a bus and race down to my local electronics parts store. This was Bardwells, which was located on one of the backstreets near the old Abbeydale Cinema in Sheffield, Yorkshire, England.

Bardwells was great. In addition to new components like transistors, resistors, and capacitors, along with simple integrated circuits like op amps, 555 timers, and 7400-series logic, they also had pieces of old electronic equipment on the shelves and boxes of 'stuff' laying around containing such delights as old rotary telephone selector relays or old telephone handsets. It was an unusual day when I didn't come away with some new little treasure to play with. As a point of interest, Bardwells (**www.bardwells.co.uk**) is still in business, although they've moved to the main road.

The big red button!

As I have mentioned in an earlier column, yours truly happens to be the chair for the 'Processors and Programmable Devices' track at the forthcoming *Design West Conference and Exhibition* (**www.ubmdesign.com**), which is to be held from 22 to 25 April, 2013 at the McEnery Convention Center in San Jose, California. In addition to some amazing papers on tele-presence robots, creating designs for space applications, embedded speech, embedded vision, and all sorts of other things – all of which will be presented by a wide range of experts – I will be giving a couple of papers myself.

One of my offerings is titled 'Danger Will Robinson! How Radiation Can Affect Your Embedded Systems' (**www.ubmdesign.com/sanjose/schedule-builder/session-id/43**). In this paper, I will start off by introducing basic concepts, such as ionising versus non-ionising radiation, and the ways in which both types can affect electronic components and systems. I will also be discussing some of the ways in which we can create radiation-hardened devices and radiation-tolerant designs.

As part of this, I've decided to build a sort of stage prop. I started with an interesting wood-and-leather decorative case that I picked up from Amazon. The next step was to add some switches and light covers, as shown in the photograph. I used three antique telephone switches (I'm thinking circa 1960s) that I picked up off eBay. I also used three antique faceted light covers (from top to bottom, we have green, amber, and red) with chrome highlights, sent to me a couple of weeks ago.

After I've discussed the concept of non-ionising radiation and how cellphones can affect electronic systems, I will explain how this case contains a sensitive piece of antique electronic equipment. I will then activate the three switches – one at a time. When the first switch is activated, the red light will start to 'breathe' (casually fading up and then back down, over and over again). When the second switch is activated, the red light will be extinguished and the amber one will start to breathe. And when the third switch is activated, the amber light will be extinguished and the green one will start to breathe.

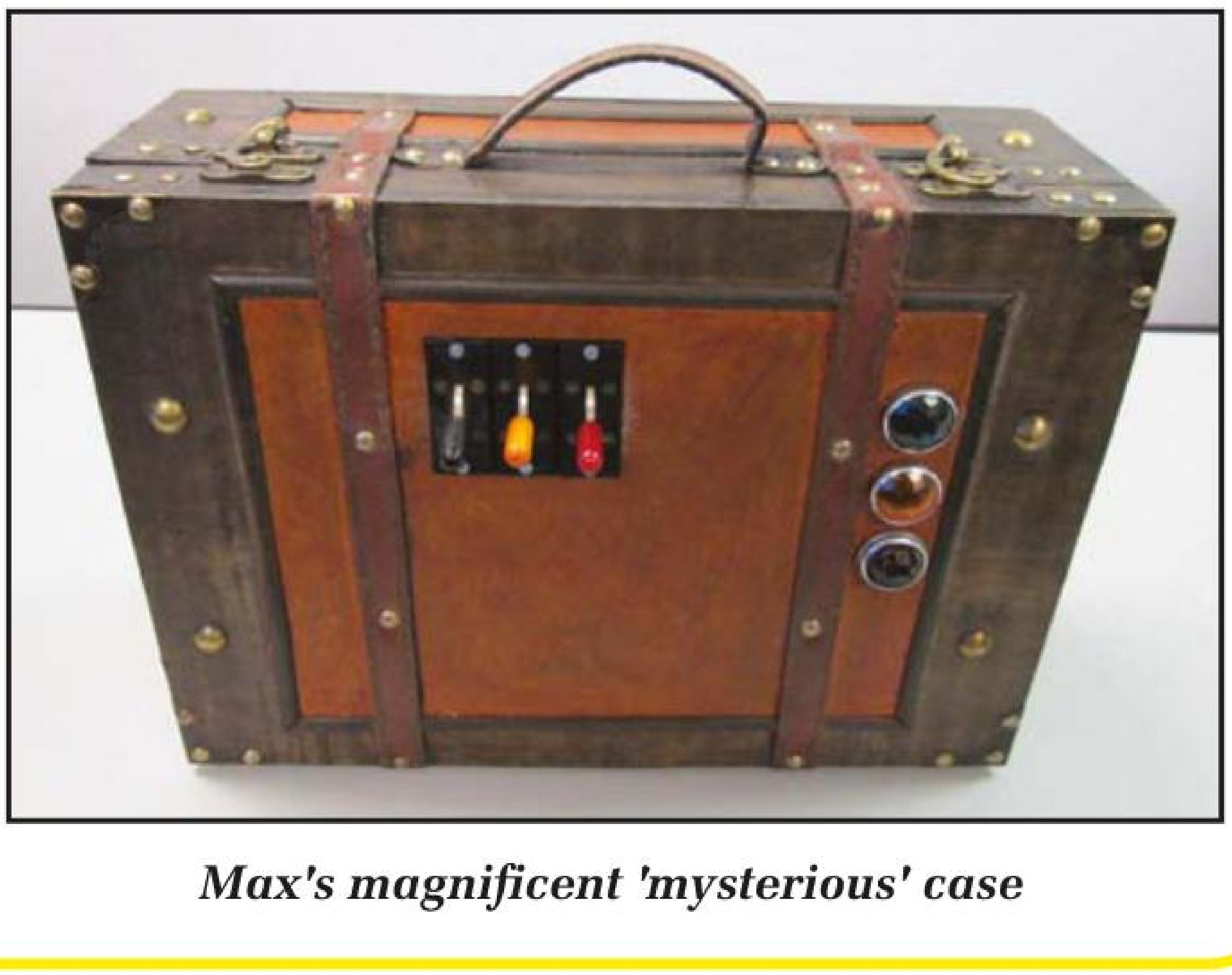
Next, I plan on standing my iPhone in front of the case with the iPhone's screen facing the audience. I will explain that smartphones 'ping' the local radio tower every three minutes or so, but that my case is shielded against such effects.

I will then continue with my talk, leaving the case on the table facing the audience with the green light happily breathing away. At the end of my talk, just as I ask 'Are there any questions,' a friend lurking surreptitiously at the back of the room will place a call to my iPhone. As soon as the iPhone's screen lights up and we hear the well-known calling signal (there will be a microphone strategically placed to pick this up), the green light will be extinguished, the red light will start 'panting' (cycling on and off rapidly), and an audible alarm will start to sound.

Stop mocking me!

The thing is, I needed some form of light source behind my red, amber, and green covers. Light-emitting diodes (LEDs) were the obvious choice, but when I tried them they looked horrible (like little point sources). I was chatting to someone about this, and they told me about a store called Mock Electronics (**www.mockeletronics.samsbiz.com**). This emporium is located in downtown Huntsville, Alabama, USA, which is where I currently 'hang my hat.'

The frustrating thing is, I've been moaning and groaning about the lack of such a store for years. Yes, of course, we have the Internet, but that's not the same as rooting around an old electronics store. All I can say is, Mock Electronics boasts the most eclectic range of modern and antique electronic components and products that it has ever been my good fortune to see. In future columns I will show you some pictures of some of the amazing things I've discovered there, along with the solution to my suitcase lighting quandary. Until next time, have a good one!



Max's magnificent 'mysterious' case

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

Semiconductors galore!

WHEN I first became interested in electronics, which was admittedly a good many years ago, semiconductors were relatively new. In fact, many of the published circuits were based on valves (tubes) and did not actually use any semiconductors at all!

Those that did use so-called 'solid-state' components were based on discrete transistors, and possibly a diode or two. The situation is very different today, and even with some rationalisation of product ranges in recent years, the range of semiconductor devices on offer remains vast.

I suppose this vastness is to some extent a delusion, since many of the devices are 'much of a muchness', with only minor differences from one to another. In some cases, the only difference is the type of encapsulation or leadout configuration, with the same chip being listed under several different type numbers. Even allowing for these factors, the range of semiconductors currently available can be a bit bewildering.

Simple diodes and transistors are still available, as are numerous variations on these. Then there are the various ranges of integrated circuits, sensors, and other specialised semiconductors. The current range is so vast that it is not possible to cover all types here, but the main categories, apart from integrated circuits, will be considered.

Flow control

The simplest type of semiconductor is the diode, which has just two leadout wires. Its basic function is to allow a flow of current in one direction, but to block it in the opposite direction. In terms of conventional current flow the device conducts with the positive and negative supplies connected to the anode (a) and cathode (k) respectively.

Diodes are used in low-power applications. Diodes for use at high currents of about one amp or more are usually referred to as 'rectifiers', but apart from the fact that they can handle higher currents, they are the same as diodes.

Obviously, a diode must be connected with the *correct* polarity, and in the case of rectifiers there could be dire results if a mistake is made. Fig.1 shows the circuit symbol for a diode, and the methods of polarity marking used on most diodes and rectifiers. These are loosely based on the circuit symbol.

By far the most common method of polarity marking is to have a band on the body of the component near the cathode (k) lead. This band corresponds to the bar at the cathode end of the circuit symbol. The same method is used for most rectifiers. Diodes generally have a rounded shape, while rectifiers are more angular and possibly larger as well.

Colour band

It seems to be increasingly common for diodes to have the type number marked using coloured bands and coding that is loosely based on the resistor colour code. With more than one band to contend with there is obviously scope for confusion here.

The band that indicates the cathode end of the component should be much wider than the other two or three bands. Also, the bands should be grouped towards the cathode leadout and away from the anode one.

Due to the minute size of many modern diodes, this might not be

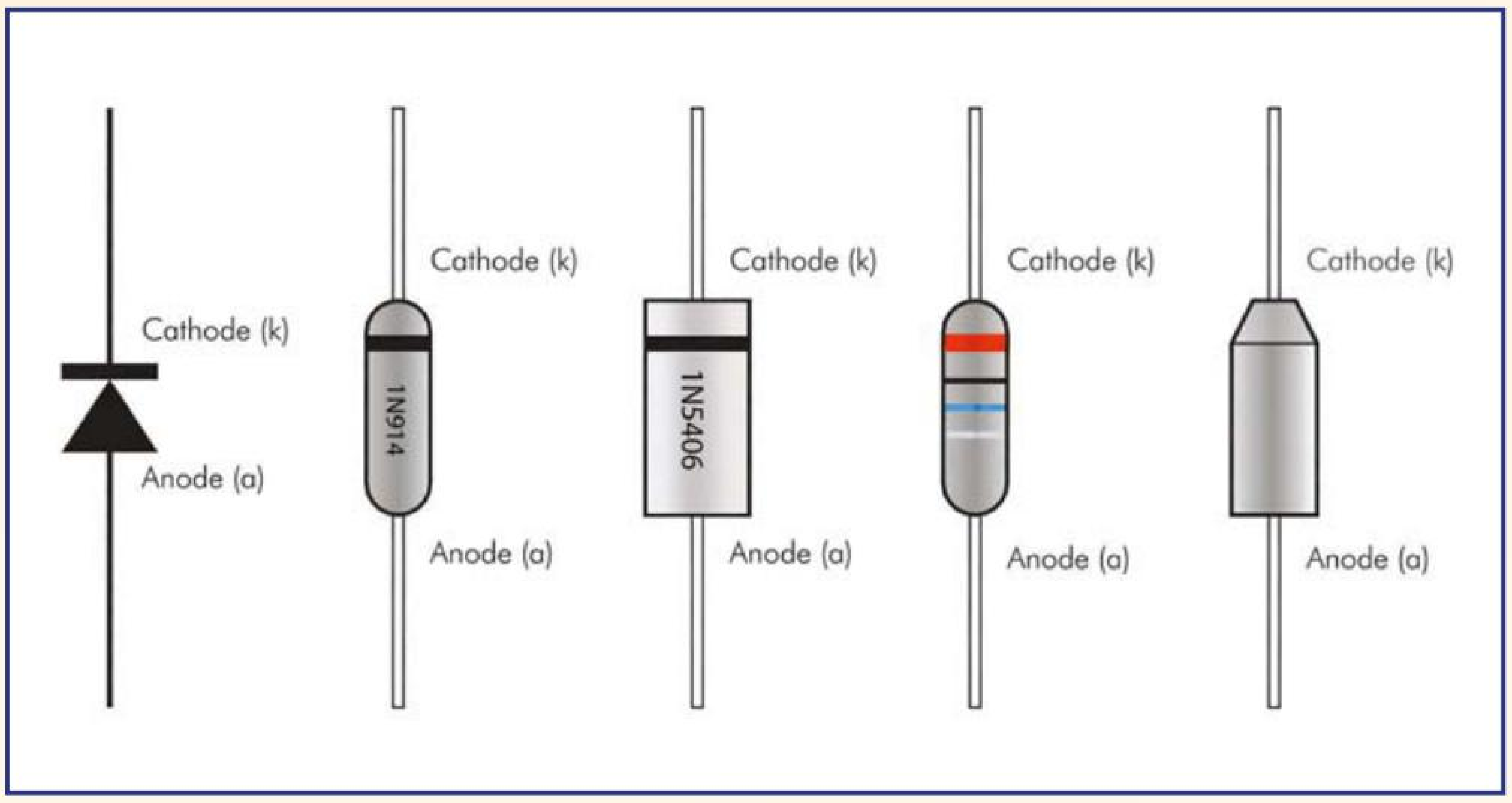


Fig.1. The diode circuit symbol (left) together with various methods of indicating the anode and cathode leads of actual components. All of these methods are vaguely based on the circuit symbol

immediately obvious, and some careful scrutiny might be needed in order to determine the polarity of a real-world diode. Some rectifiers use another variation, and this is to have the body tapered at the cathode end. This corresponds to the arrowhead part of the diode symbol, which indicates the direction in which a current can flow through the component.

Softly, softly

When dealing with diodes, it should be borne in mind that they are not the toughest of components. Some have glass encapsulations, and bending a leadout wire close to the body of one of these could easily result in physical damage occurring, possibly with the leadout wire breaking away from the body.

Germanium diodes from the pre-silicon era are still preferred in some applications due to their lower forward voltage drop. Silicon diodes and rectifiers are nearly perfect with a reverse voltage applied, allowing no significant current flow. With a forward voltage applied there is a voltage drop of typically about 0.6V to 0.7V, which is far from ideal.

Germanium diodes are better in some applications because they have a much lower forward voltage drop, albeit with higher leakage levels with a reverse voltage applied. A problem with germanium devices is that they are more vulnerable to heat damage than the more familiar silicon types. Extra care must, therefore, be exercised when soldering a germanium diode into place.

Although diodes are very basic semiconductors, they have still spawned a few specialised versions:

Schottky diodes/rectifiers

As pointed out previously, ordinary silicon diodes and rectifiers produce a significant voltage drop when forward biased. Schottky rectifiers and diodes provide a modern alternative to germanium devices, giving a forward voltage drop that is typically about one third of that provided by an ordinary silicon component.

They are generally preferred in applications that involve high frequencies. Physically, they are much the same as silicon diodes and rectifiers.

Varicaps

A variable capacitance diode, or 'varicap' as this type of component is sometimes called, exploits the fact that the self-capacitance of a diode can be altered by feeding it with a variable reverse voltage. In practice, they are normally used in pairs.

Some of these diodes are housed in normal diode encapsulations, but they are often in the form of pairs or several pairs in special encapsulations. Any project article should include connection information for any non-standard components of this type.

Zener

A Zener diode has a reverse breakdown voltage that occurs at a relatively low voltage. This would normally be undesirable, but it enables Zener diodes to be used in simple voltage stabiliser circuits.

Zener diodes are contained in normal diode-type encapsulations. Although popular at one time, technology has to a large extent overtaken them, and they are little used in modern electronics.

LEDs

An LED (light-emitting diode) is a genuine diode, and it will only light up if it is connected to the power source with the correct polarity. By far the most common method of indicating the polarity of a LED is to have the cathode (k) leadout wire a few millimetres shorter than the anode lead. Unfortunately, there is no properly standardised method of indicating the polarity of a LED. The vast majority of LEDs do conform to this method, but a minority of them either do things the other way around, or simply have two leadout wires of equal length.

Some LEDs have the case flattened slightly next to the cathode lead, but again, there is no certainty that this will indicate the cathode lead, or that it will be present at all. Matters are complicated even further by the fact that modern LEDs come in a multitude of different shapes and sizes, and the normal methods of polarity indication might not be relevant.

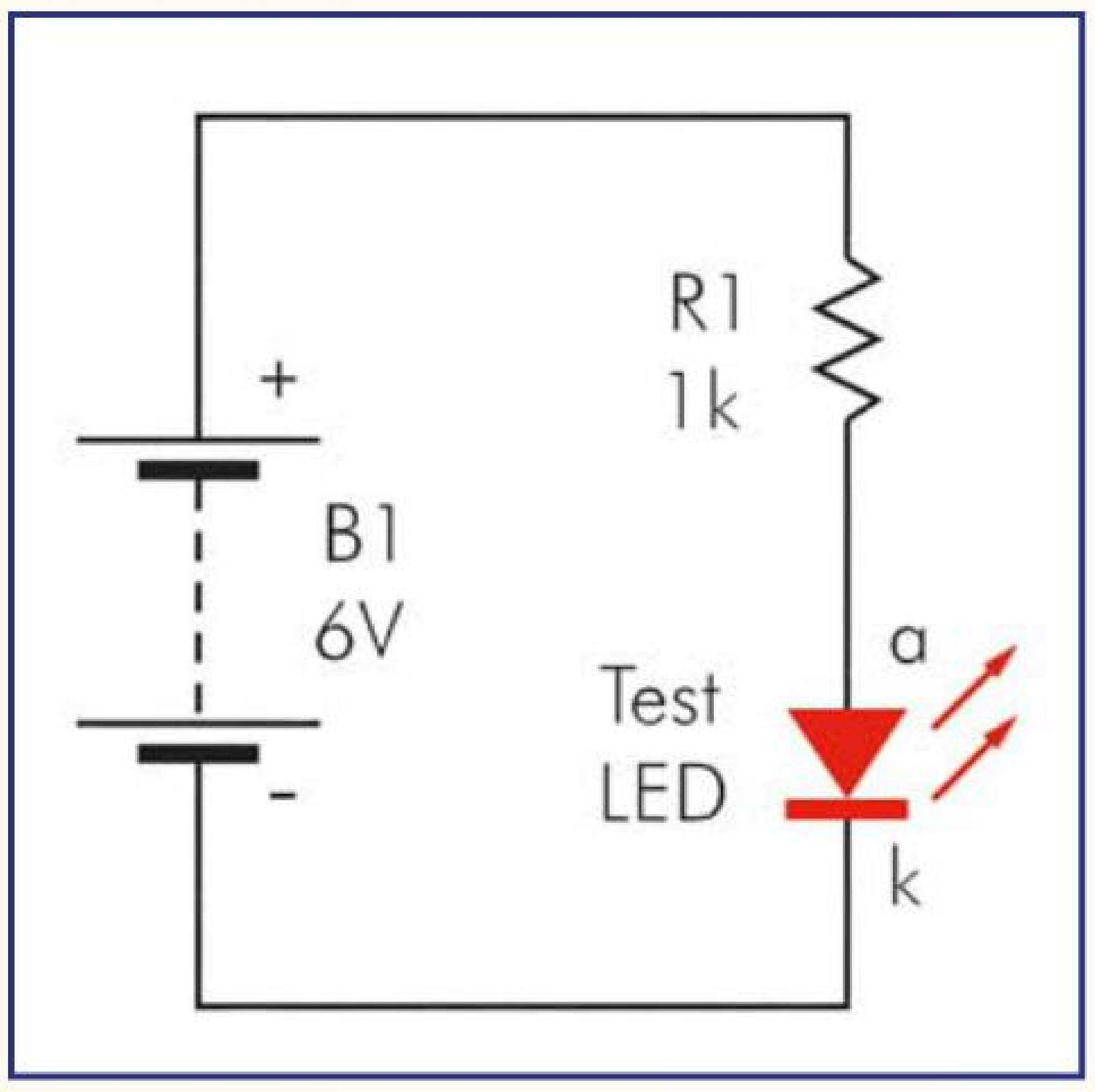


Fig.2. The LED will light up when connected as shown here, but not if it is connected the other way around. It will work just as well with any battery voltage from 3V to 12V

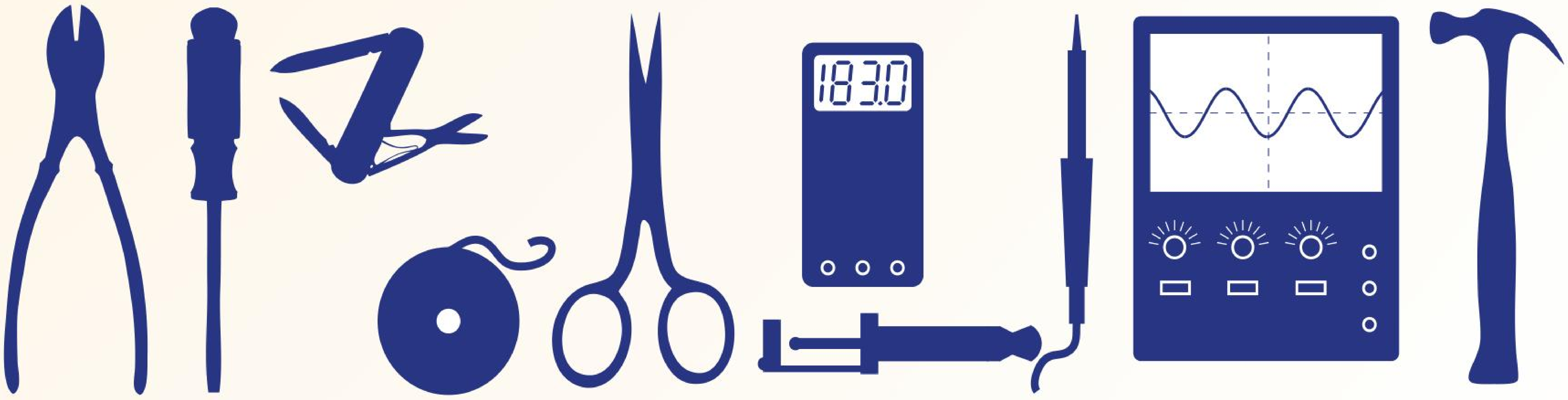
An LED should not come to any harm if it is connected with the wrong polarity. The circuit that regulates the current to the device when it is working normally will prevent any damage if it is connected with the wrong polarity. Still, it is better to get things right first time, since correcting mistakes can easily result in damage to components and (or) the circuit board.

Most test meters have a diode checking facility, but having tried a few of these with LEDs, I have yet to find one that works with this type of diode. The problem seems to be that LEDs require about 2V, before they will begin to conduct in the forward direction, which is much higher than the 0.6V or so of a silicon diode.

It is not too difficult to make a simple LED checking circuit, and something as basic as the one shown in Fig.2 will suffice. Try the test LED with both polarities, and when it lights up it has the polarity shown in Fig.2.

Transistors

Normal transistors have three leadout wires (pins) that are called the base (b), collector (c), and emitter (e). A small current flow through the base and emitter can regulate a much larger flow through the collector and emitter circuit, in other words 'amplification'.



In a digital world, I suppose that it is more likely to be a switching action provided by the collector and emitter, with a small base-emitter current being used to turn the device on.

Some transistors for use in high frequency applications have a fourth lead called the shield. However, this just connects to the metal casing of the device and is connected to the earth rail (0V).

There are two types of transistor in the form of *NPN* and *PNP* devices. *NPN* transistors are the more widely used type. *PNP* devices are essentially the same as the *NPN* variety, but operate with the opposite supply polarity.

Transistors are produced with numerous types of encapsulation, and with a variety of leadout configurations. The construction diagrams for a project should make the correct method of connection perfectly clear, and there may well be some assistance in the form of a leadout diagram, like the example shown in Fig.3.

It is the convention for this type of diagram to show the device as seen when looking 'underside' to the leadout wires. This is potentially a bit confusing, since you actually see the device from the top when fitting it to the circuit board. It is also the opposite of the convention for integrated circuit (IC) pinout diagrams, which are normally top views.

Do not assume that two different transistor have the same leadout configuration because they have the same encapsulation. In the example of Fig.3, the BC257/8/9 and BC547/8/9 transistors have the same TO92 plastic case, but the leadout configurations for these two sets of devices are completely different. Most types of encapsulation, perhaps a little unhelpfully, are used with more than one leadout configuration.

Plastic power

Power transistors are much the same as any other transistors, but as the name implies, they are used in applications that involve relatively high power levels. In order to handle high powers, it is usually necessary for power devices to be bolted onto a heatsink. This can be a something as basic as a small metal strip, but is often a large and elaborate piece of metal having dozens of fins.

Modern power transistors are mostly of the 'plastic power' variety, which simply means a rectangular plastic case fitted onto a larger rectangle of metal (Fig.4). The latter has a hole that enables the device to be bolted to a heatsink.

As with normal transistors, the leadout diagrams for power devices are normally base views. In other words, they show the device as seen when looking at the metal plate on its underside. The collector terminal often connects internally to the metal plate, and in some cases it is necessary to insulate the plate from the heatsink using one of the special insulating kits that are available.

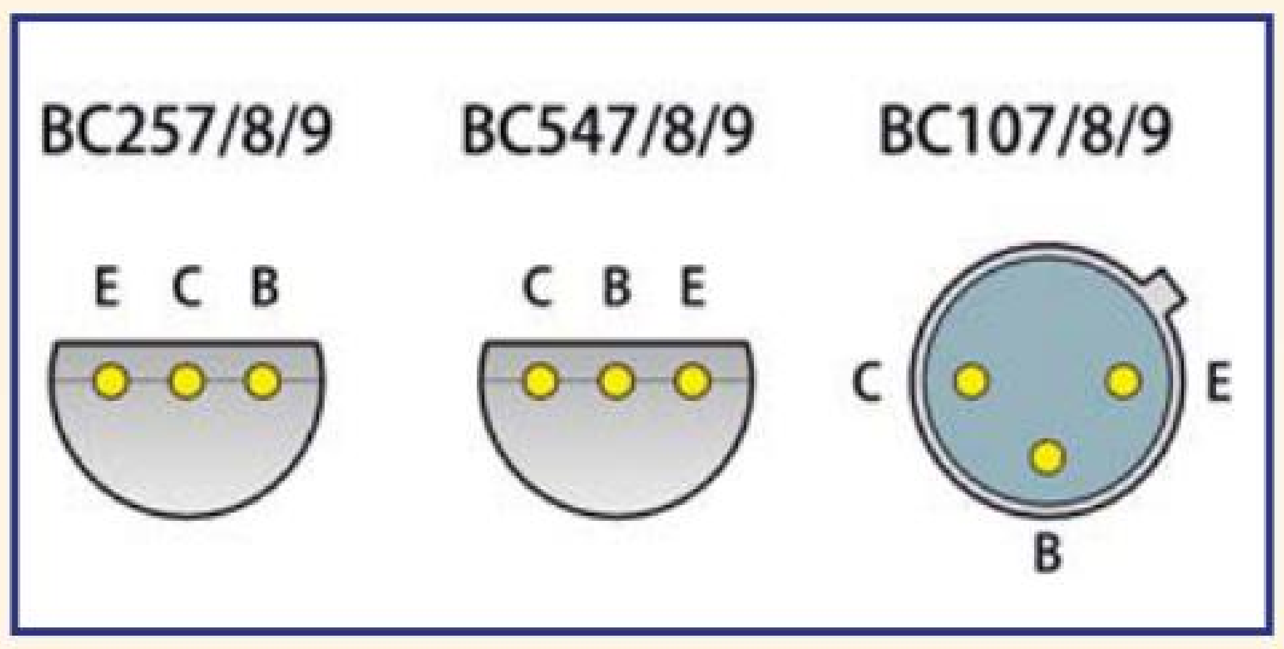


Fig.3. Transistor leadout diagrams are conventionally base pinout views. There can be more than one leadout configuration for each type of encapsulation, as in the left and centre examples here

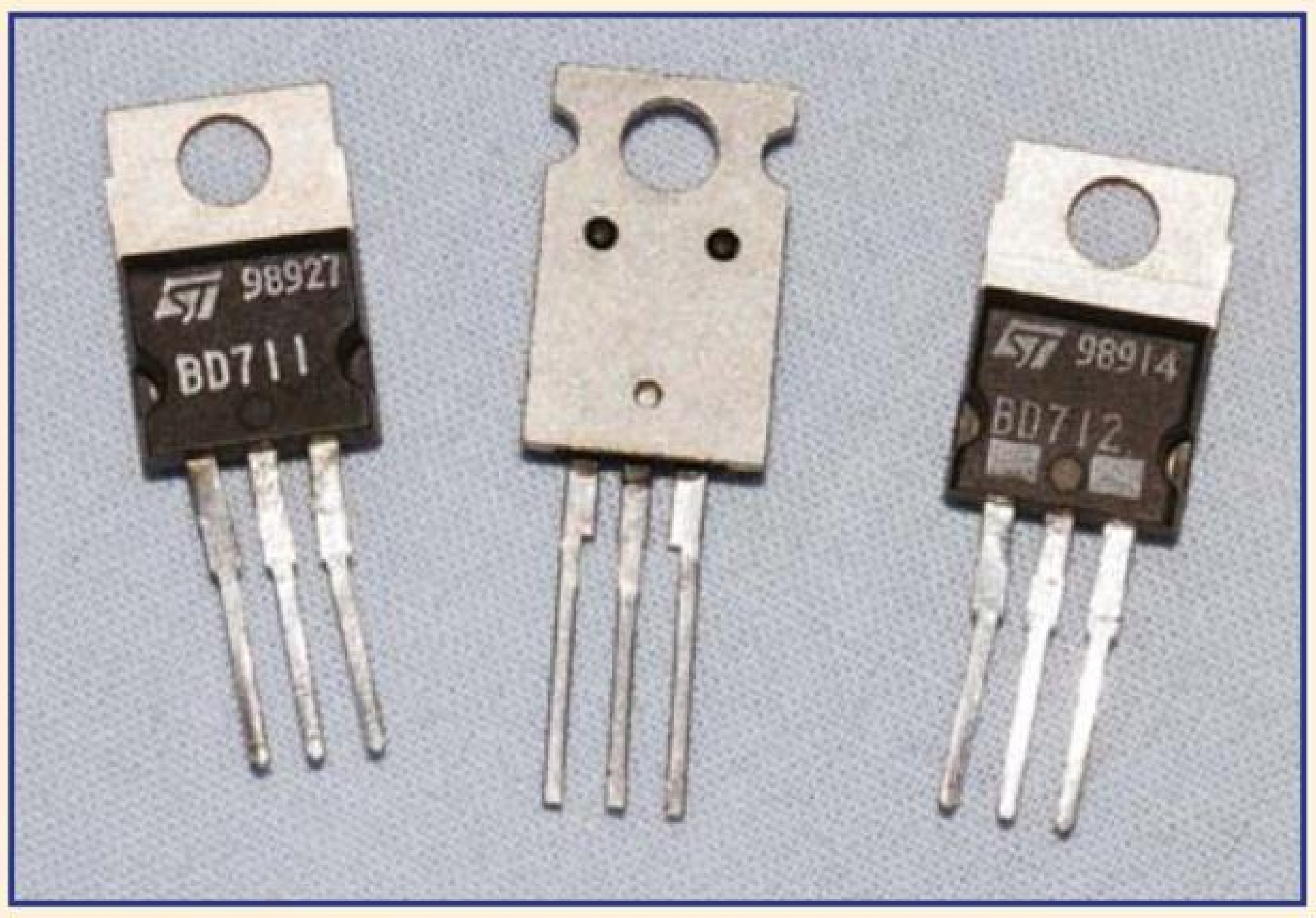


Fig.4. Three plastic power transistors. The metal underside (as seen in the middle device) normally fits against a heatsink that helps to dispel excess heat and prevent the device from burning out

Unijunctions

There is a special type of transistor called a unijunction transistor, or UJT, which has two bases, an emitter, and no collector terminal! These are used in a simple type of oscillator called a relaxation oscillator. This is a device that has succumbed to progress, and the UJT is now obsolete. This is perhaps a shame, they were fun to use, but time marches on.

FETs

The field effect transistor, or FET, technology is used in many integrated circuits, including most logic types. Unlike ordinary transistors, FETs draw only minute input currents and they are voltage rather than current operated. Individual FETs have never been used a great deal though, and few are on offer these days.

There are two types, which are the junction gate and MOS (metal-oxide silicon) varieties. The latter require the anti-static treatment afforded to MOS-based integrated circuits. Their gate (g), drain (d), and source (s) terminals roughly correspond to the base, collector, and emitter terminals (respectively) of 'ordinary' transistors.

Triacs, diacs, and thyristors

A triac is a switching device that is used to control AC loads. A small current applied to its gate terminal turns on much higher currents through its other two terminals. These are usually called mains terminals one and two (MT1 and MT2).

A thyristor, which is also known as a silicon-controlled rectifier or SCR, is similar, but is used to control DC loads. Like a triac, a small gate current will switch the device on, and it will then conduct between its anode (a) and cathode (k) terminals.

A diac is a two terminal device that is used to trigger triacs in some power controller applications. Some triacs designed specifically for power control applications have a built-in diac.

Although some diacs have diode/rectifier style encapsulations that give the impression that they are polarised components, they can actually be connected either way around. Triacs and thyristors have standard transistor type encapsulations. Leadout diagrams for triacs and thyristors, like those for transistors, are normally underside pin views.

Building bridges

Rectifiers are often used in a 'bridge' circuit, which is basically just four rectifier diodes connected in a ring. An AC signal from a transformer is applied to two of the leads, and a raw DC output signal is available from the other two leads. Obviously, a bridge rectifier can be made from four individual rectifiers, but they

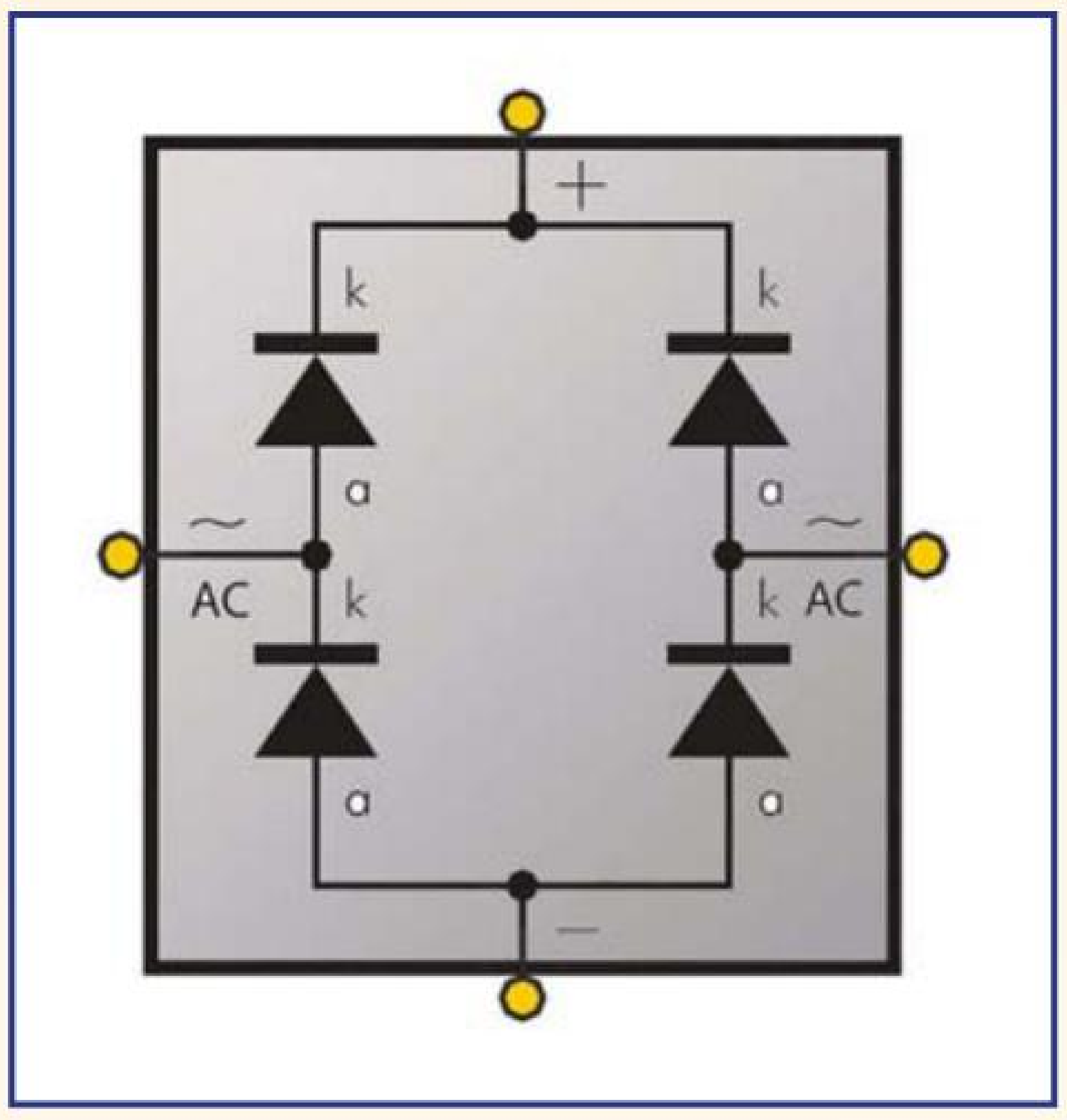


Fig.5. A bridge rectifier is used in power supply circuits to convert an AC input signal to a raw (unsmoothed) DC output type. The two leads marked 'AC' or with '~' signs can be connected to the AC input signal either way round

are available as single components containing four rectifiers (diodes) connected in the appropriate fashion.

Bridge rectifiers come in a variety of shapes and sizes, but they are mostly in the form of squares or discs of plastic with four stout leadout wires. Whatever type of encapsulation is used, it will usually have markings that clearly indicate the correct method of connection. In some instances, there is a circuit diagram moulded into the case, but the more usual method is to have the AC input leads marked 'AC' or with with '~' signs, and the DC output leads marked with '+' and '–' signs (Fig.5).

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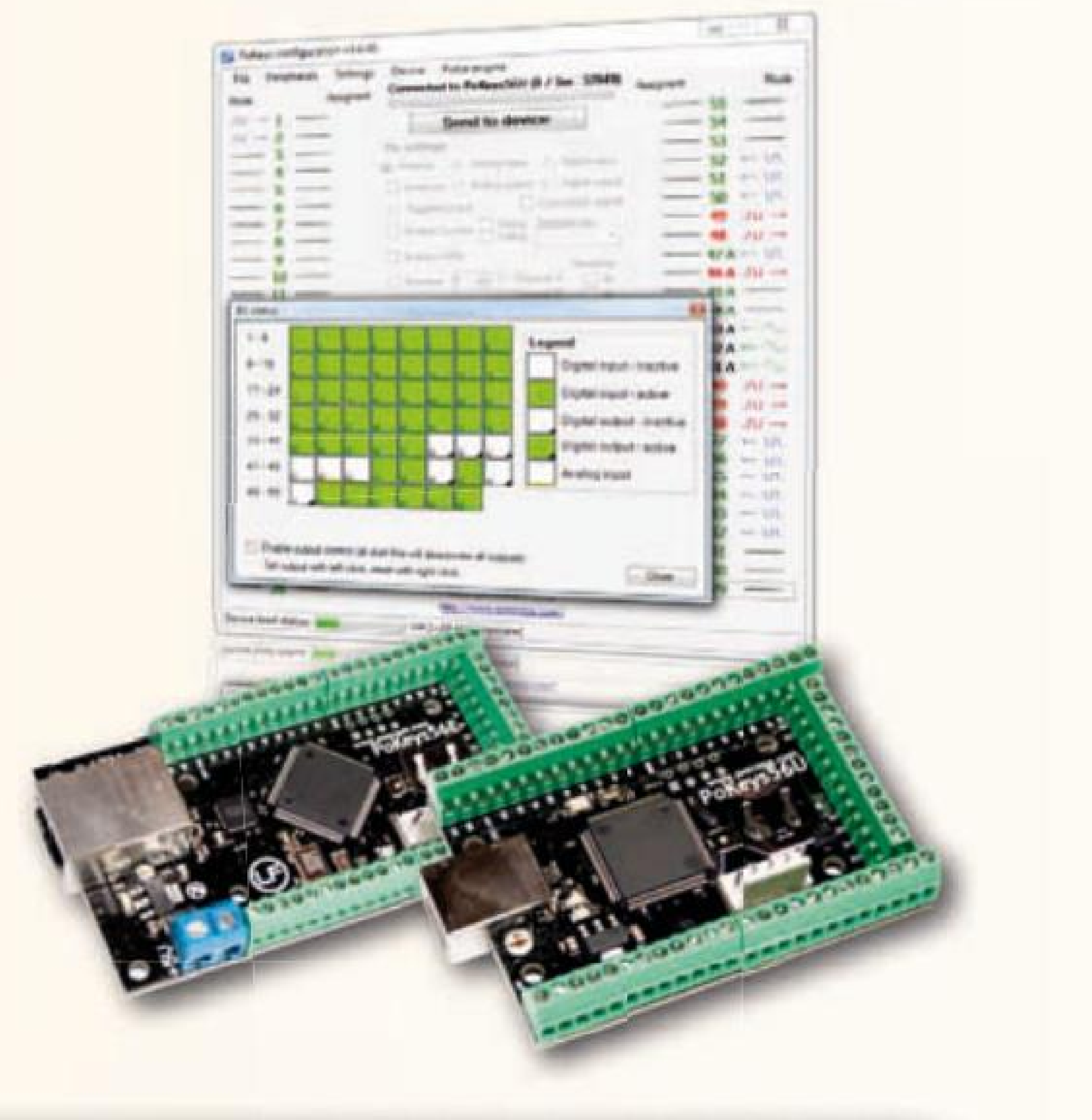

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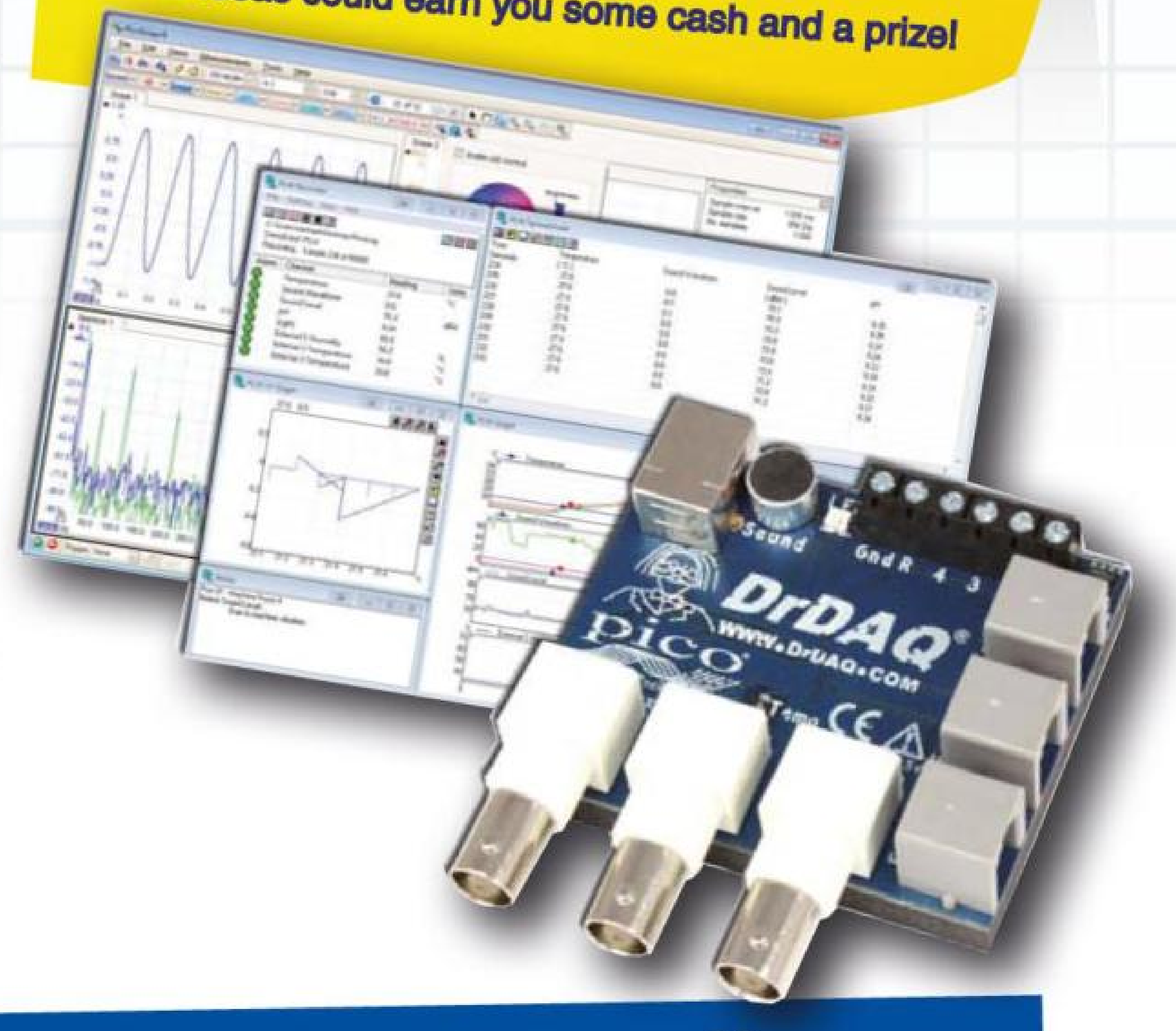

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Low-cost auto-dialler for landline phone – On-call

MY low-cost auto-dialler using a mobile phone was published in *Ingenuity Unlimited* last autumn (Nov 2012). I knew that it could be used as my house security alarm, but it would perhaps be more suited as a vehicle alarm.

Unfortunately, I have never owned a car that any self-respecting car thief would take a first, let alone a second look at, so I never bothered to install a security alarm. In fact, I always felt that my insurance agent and the Inland Revenue would be glad if someone stole my car for the scrap value. Then I would have to buy a new one, thus paying a higher insurance premium and, of course, more taxes.

I later realised, however, that this was not a sensible plan, since it would involve obtaining a separate mobile account for a line I expected never to need! So, I thought, why not make this design work on the landline.

For such a design, there is one problem – using a landline phone, one has to wait for the dialling tone before dialling can start. (Even today, 25 years or more since the first 'press button' phones arrived on the market, some speed-dialling people still get the wrong number because they start keying digits before the dialling tone is fully established.)

Phone preparation

There are two ways of accessing the local line when the alarm is triggered. First, by connecting a relay across

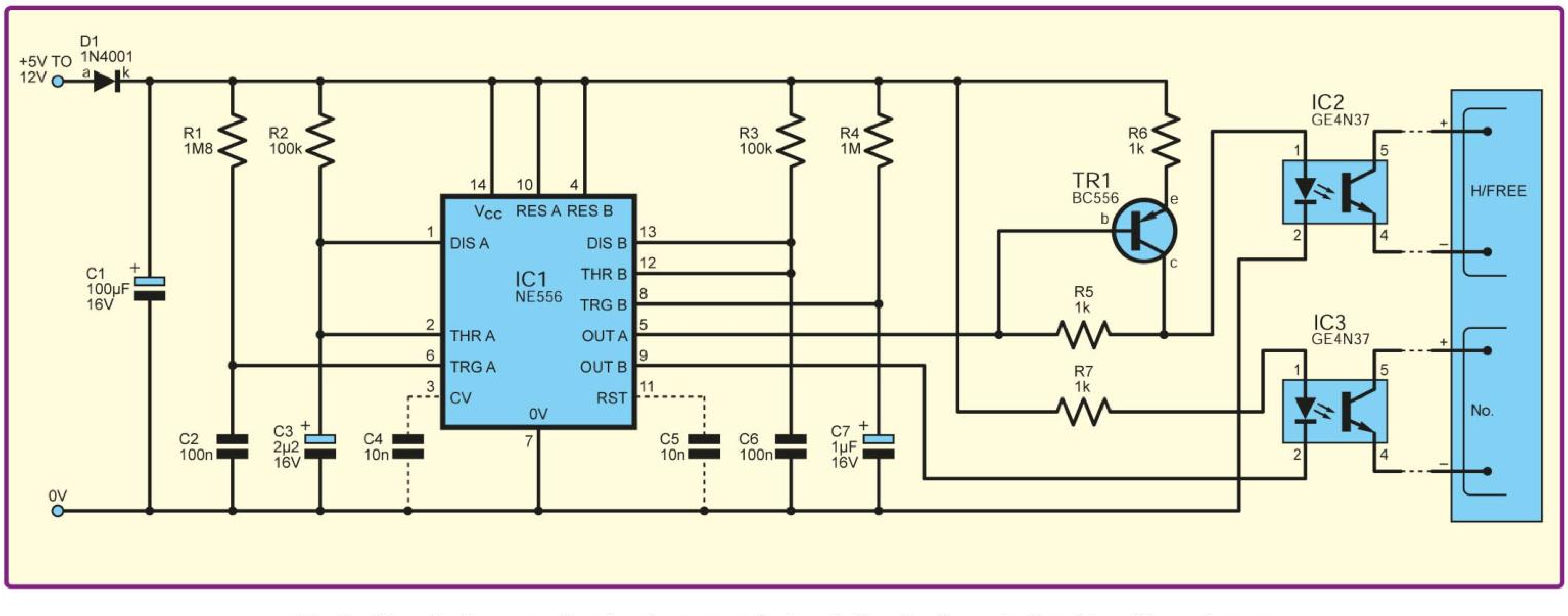
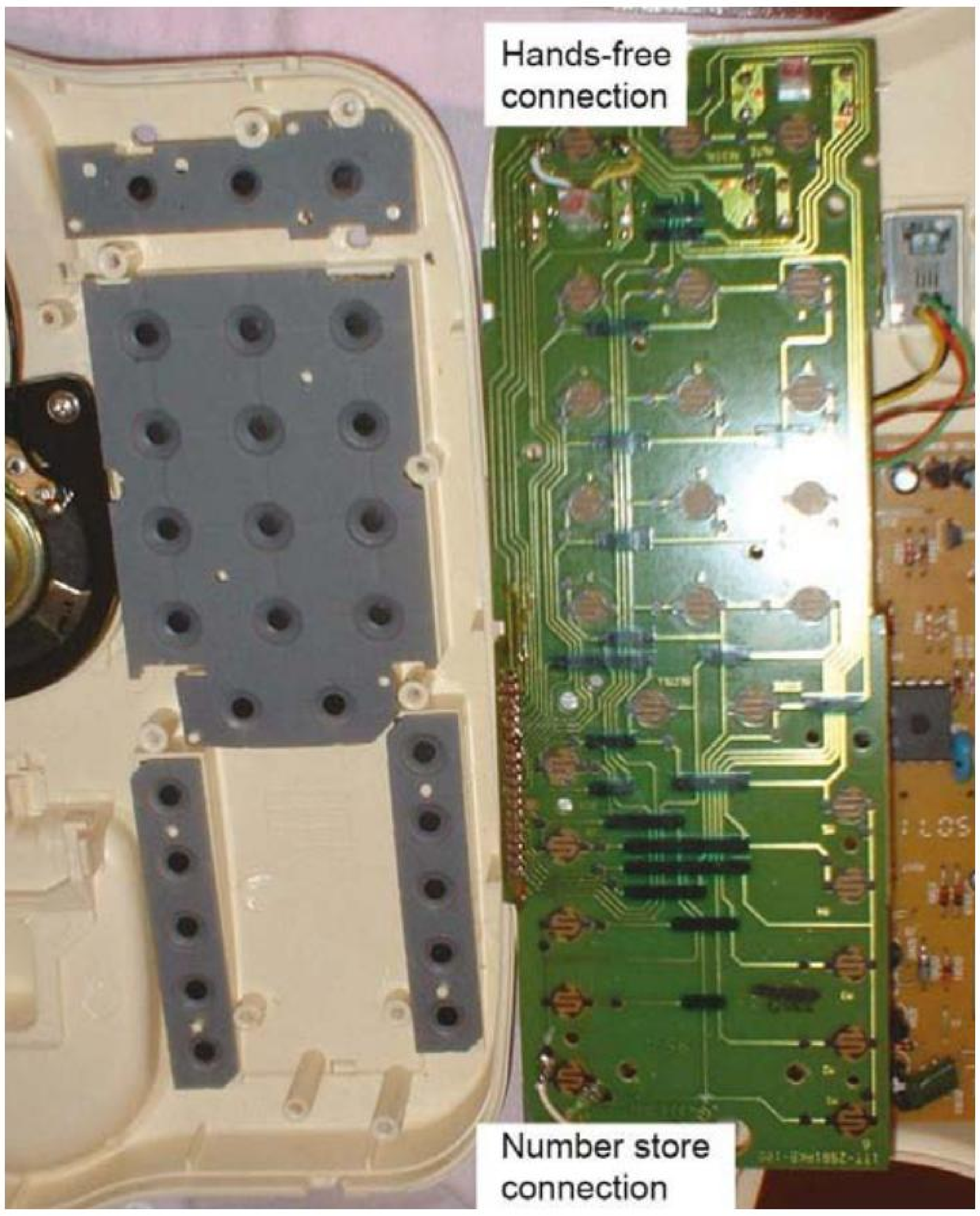


Fig.1. Circuit diagram for the low-cost Auto-dialler for 'hands-free' landline phones



Locating the hands-free and number store connections on a typical keypad board

The Auto-dialler circuit board wired to the telephone

the switch that is operated by the switch hook, but that involves a rather bulky component. Second – and much simpler – use a 'hands-free' dialling phone with number storage facility. (Do make sure you are not altering a rented phone.) On the keypad PCB, attach two wires on either side of the hands-free button track, then do the same with a number storage position and lead out (see the photo above).

Circuit

Refer to the circuit diagram (Fig.1); both halves of the 556 dual timer (IC1) are wired as a monostable switch, but with different duty times. Side A is set to five seconds and side B one second. The circuit is energised when the alarm is triggered.

Both timers are set on as the supply rises, the output at pin 5 is used to feed current to opto-coupler IC2, which mimics the hands-free switch selecting a dialling tone. The output at pin 9 runs for about one second and is connected to the cathode of opto-coupler IC3. When pin 9 is timed out it enables IC3 to conduct through resistor R7, thus selecting the number stored under this position, and dialling takes place since IC2 is still holding the dialling tone.

The network will terminate the call if it is not answered after a preset time. It will also be terminated when the answerer hangs up. In either case, the local line will be left in an engaged or open state if the hands-free switch is not operated to shut it down.

This is where transistor TR1 comes in, along with the dual role of capacitor C1. As the alarm shuts down, removing the supply voltage, C1 must discharge and the shortest route is through resistor R6 (1kΩ), TR1 and the opto-coupler of IC2, which again mimics the hands-free switch to clear the line.

It can be seen that this arrangement could be used to operate another circuit when the primary side shuts down, much the same as a changeover relay.

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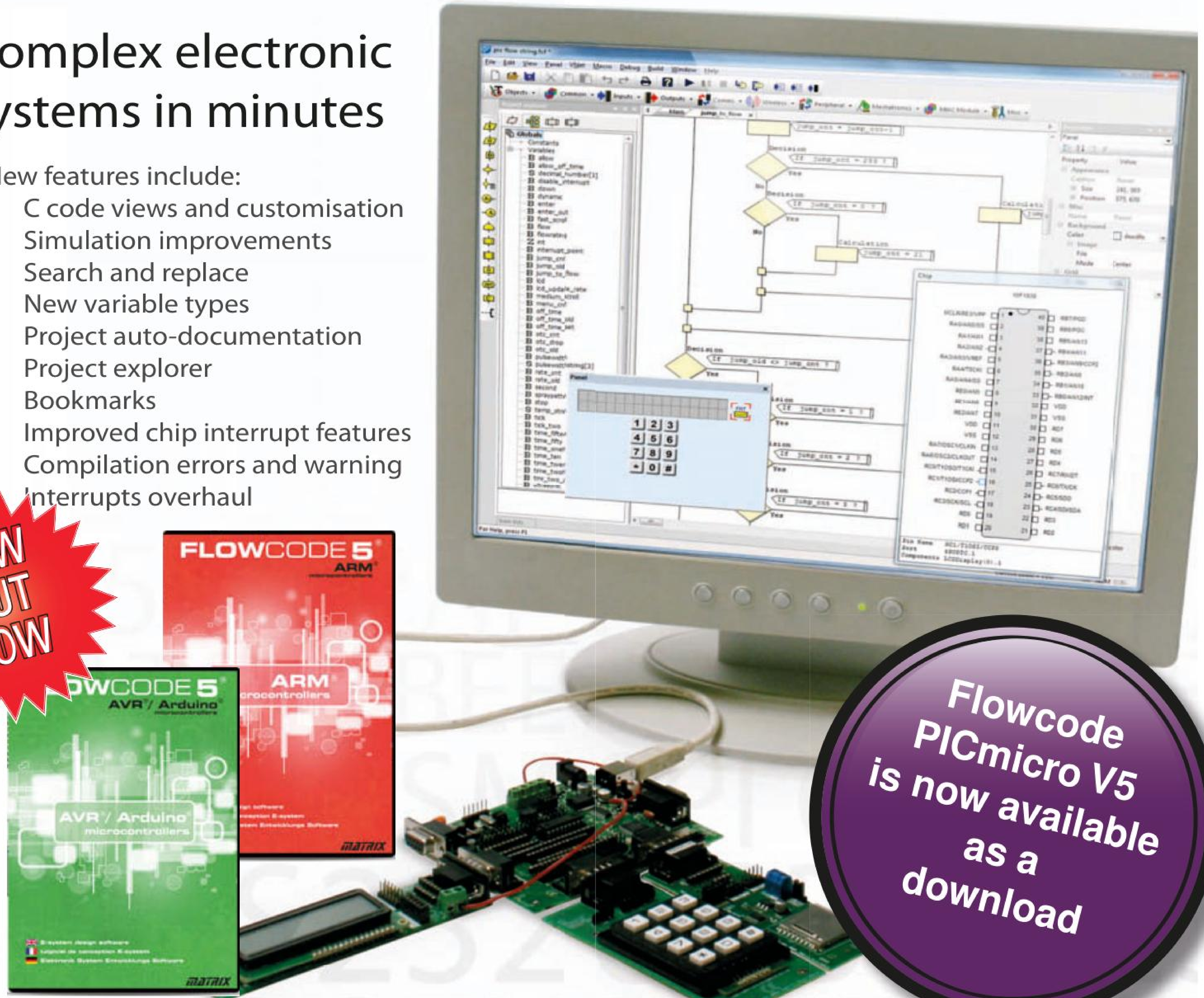

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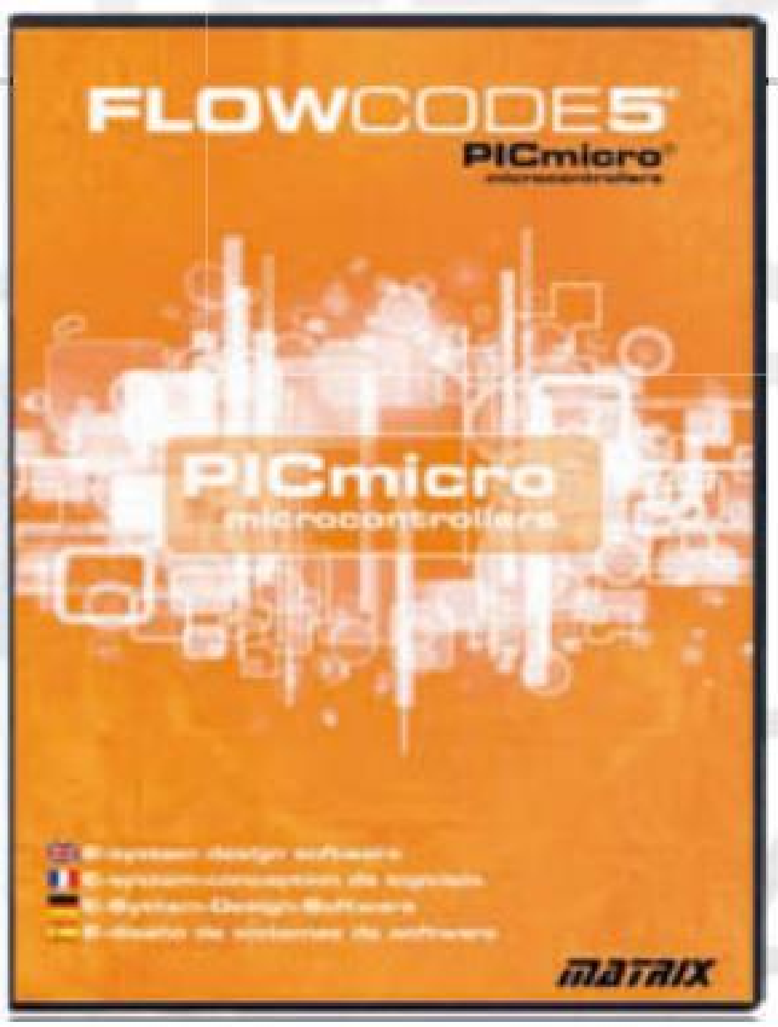

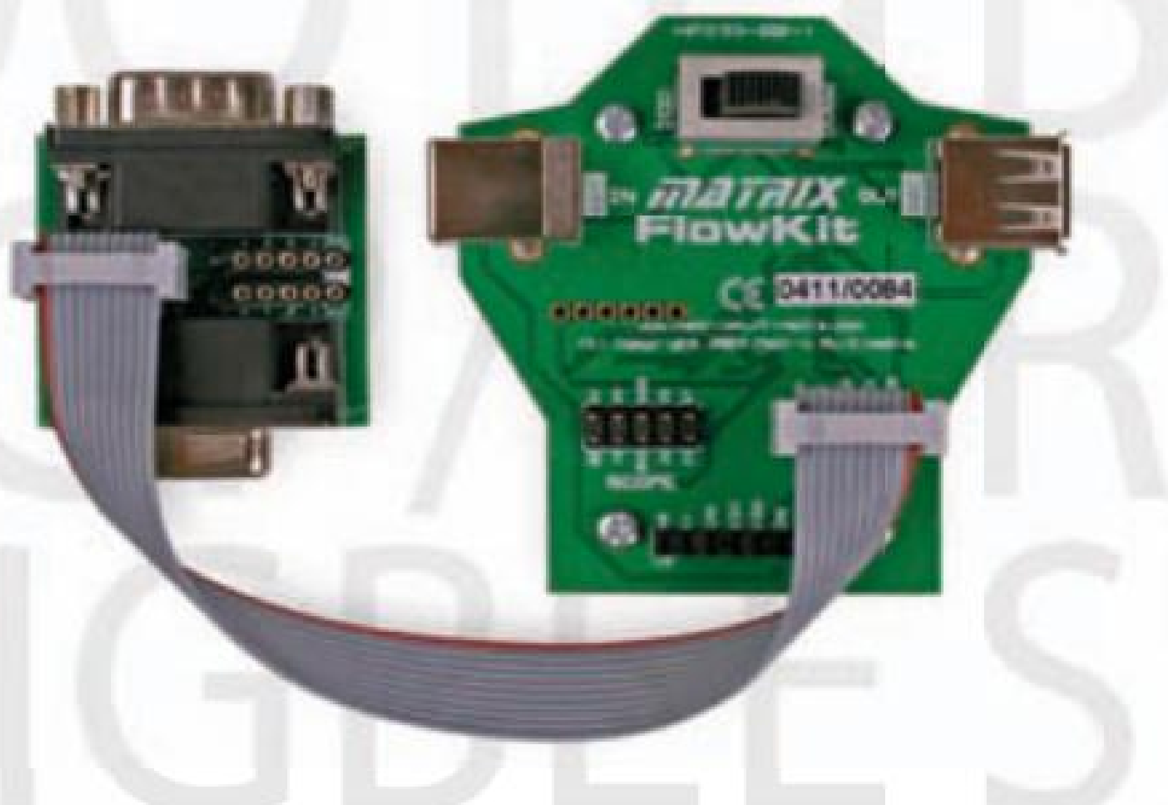

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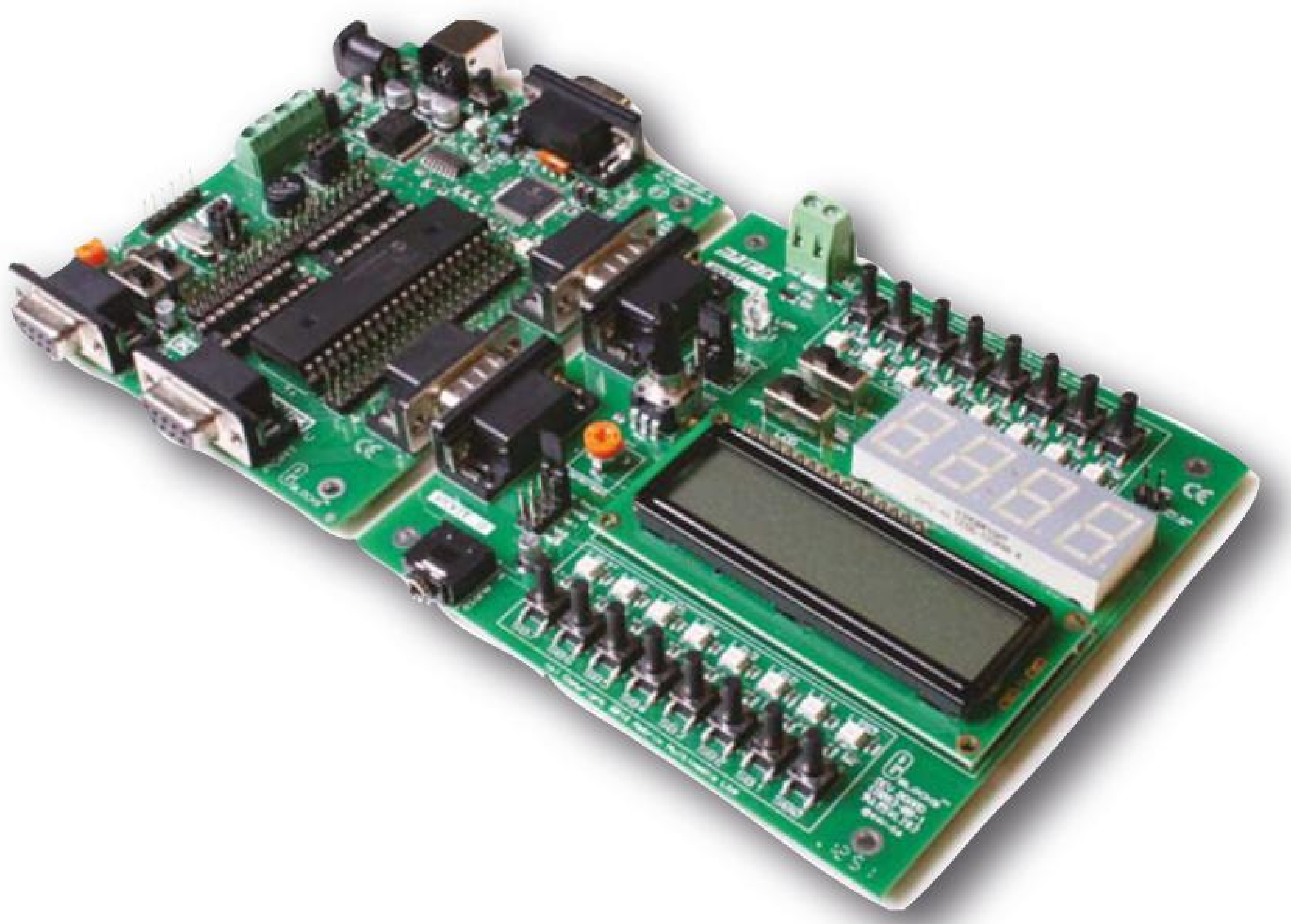

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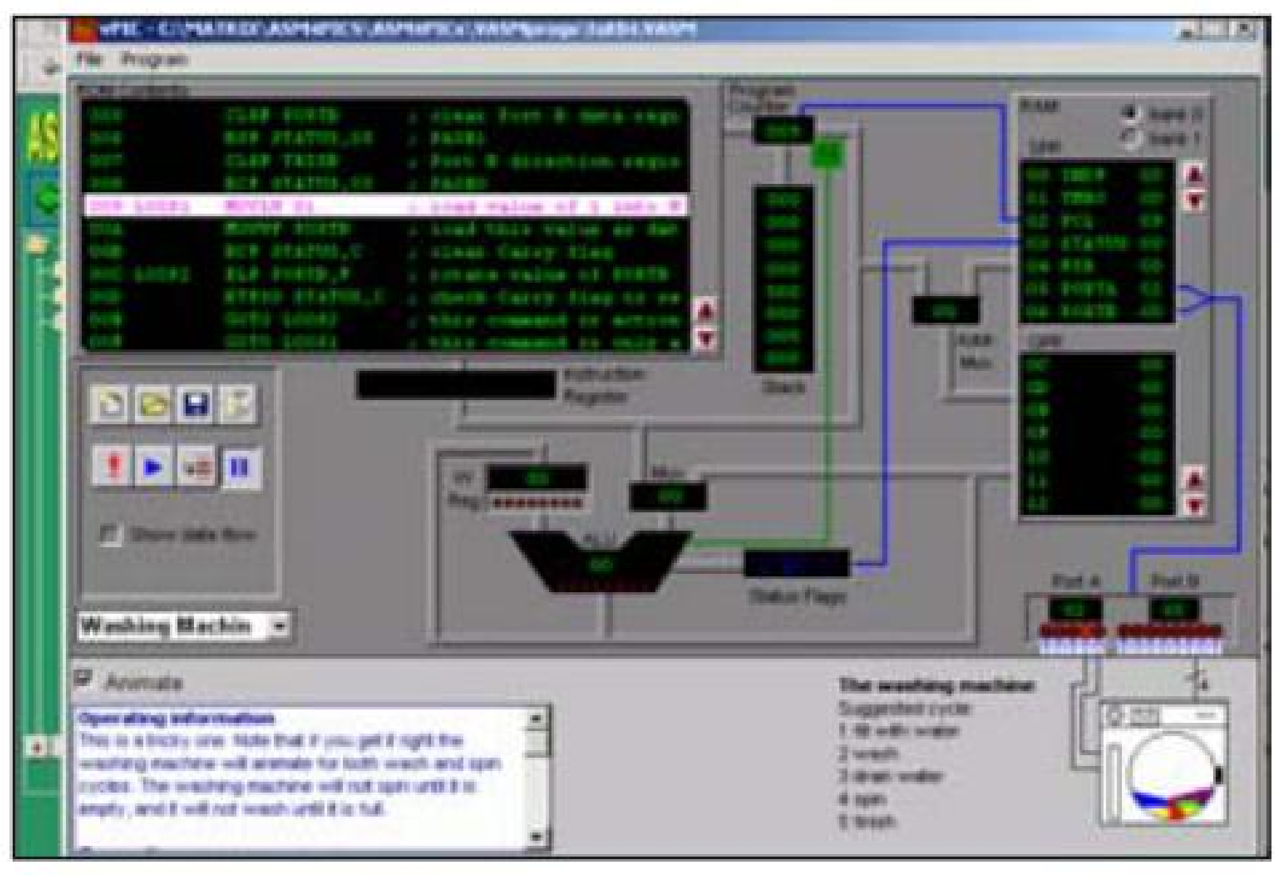

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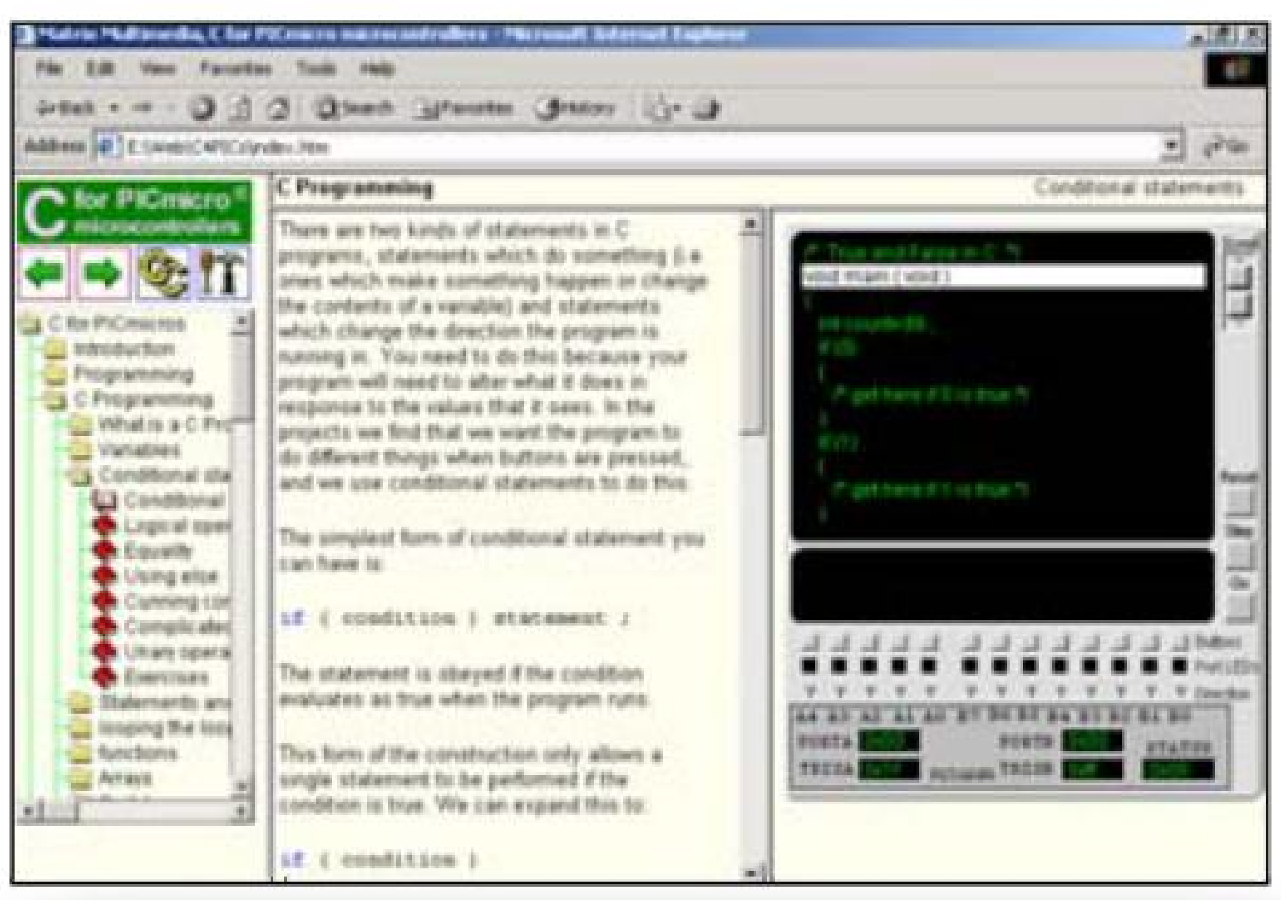

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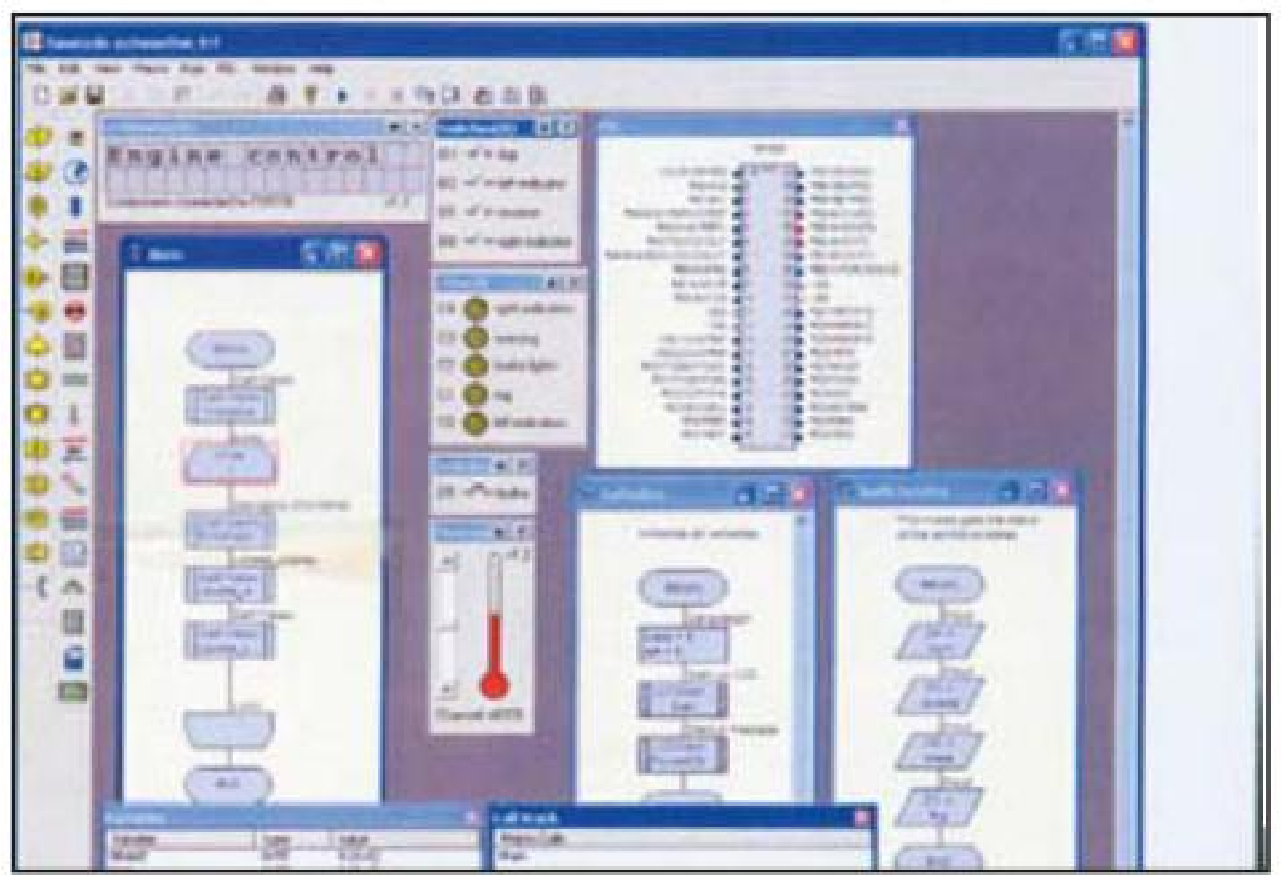

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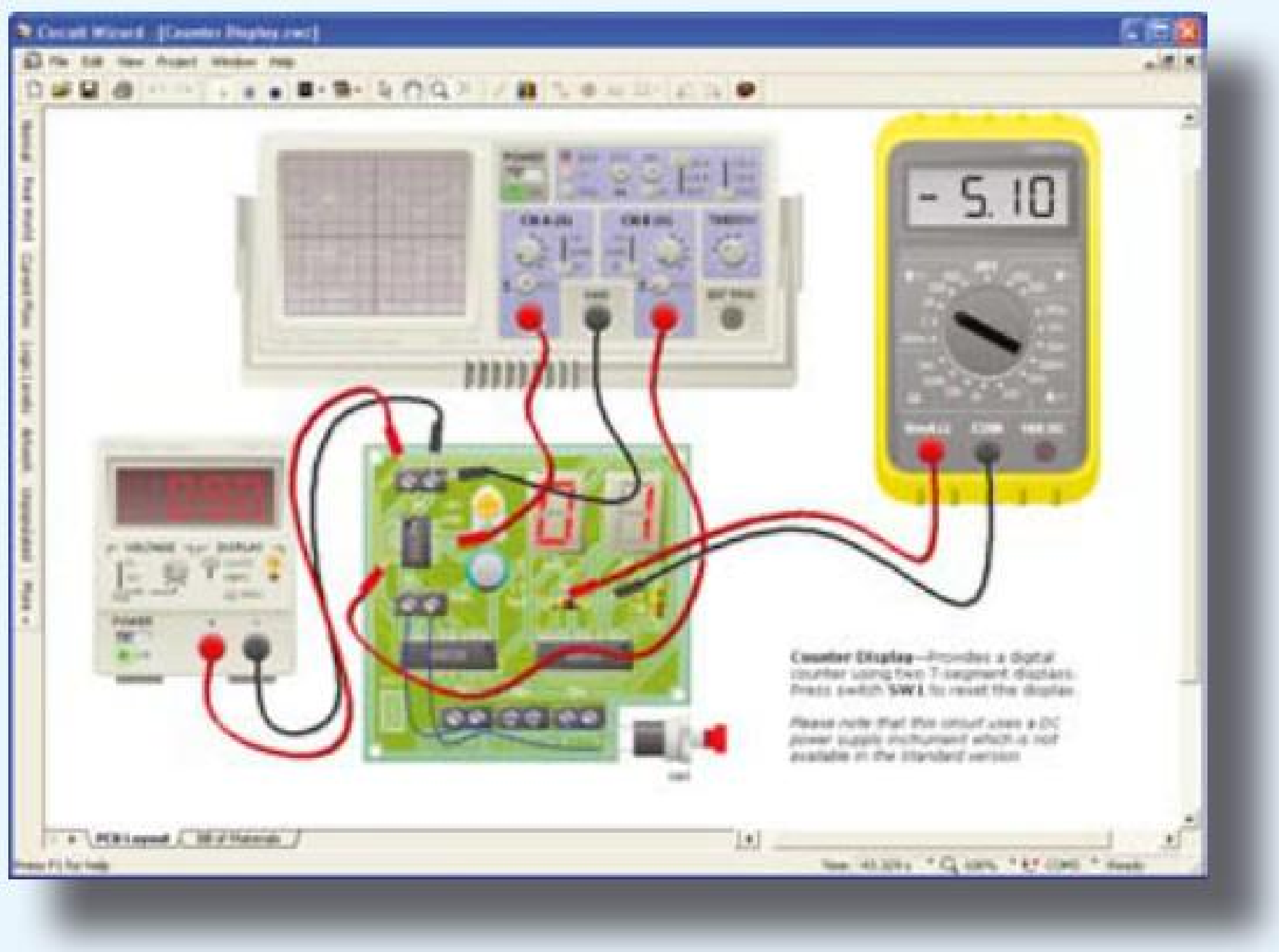

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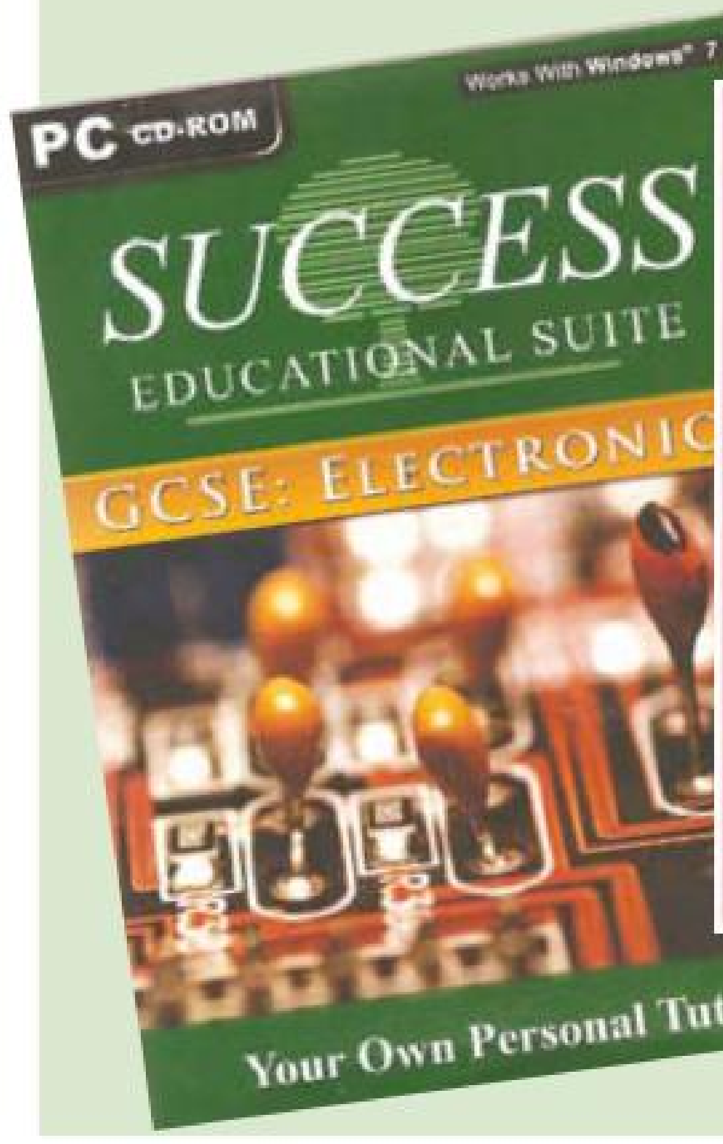

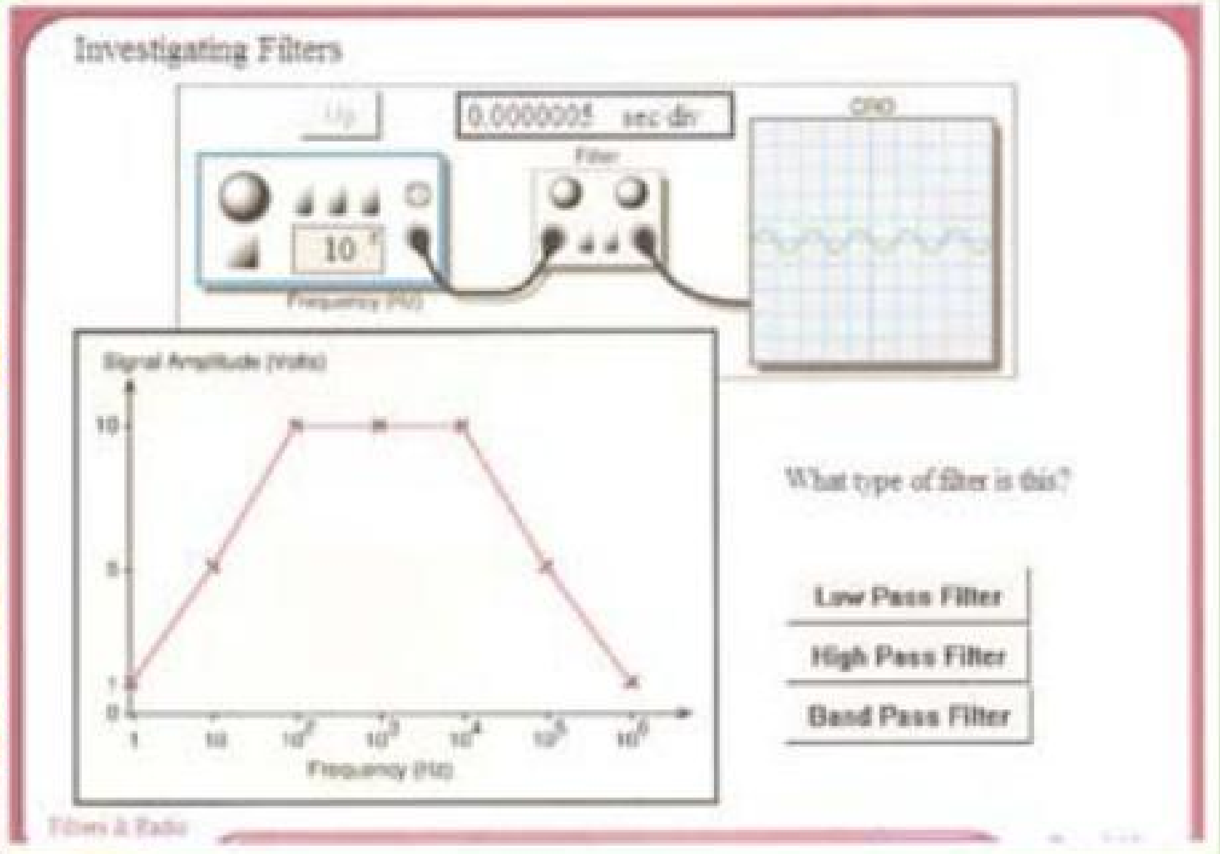

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NET WORK

by Alan Winstanley

A pure picture

IN April's issue, the Youview DTR-T1010 set-top box produced by Humax was mentioned. This set-top recorder has a wired Ethernet port to stream web-delivered Catch-up TV channels and video on demand, features missing on similar Freeview+ recorders.

Following a silent OTA update, the 'apps' in Humax recorders can be configured online at **myhumax.net**, an idea that the DAB radio manufacturer Pure (**www.pure.com**) adopted several years ago. Internet radios, including the excellent Pure Evoke Flow, have built-in Wi-Fi that hooks directly to a wireless router, to pull in Internet-based radio channels from anywhere in the world, or play 'catch up' radio programmes instead. Channels can be shortlisted or grouped together into 'favorites' using a Pure Connect web account (formerly known as 'The Lounge').

Pure offers much more added value content though, including sound tracks of birdsongs, soothing ambient sounds to fall asleep to, or busy typewriters, motorbikes or footsteps in the snow. You can experience Pure audio services for yourself by visiting **http://connect.pure.com**

Pure has not been idle in the TV set-top box market, having soft-launched in late 2012 their own Freeview+ HD recorder. The Pure Avalon 300R Connect is available with 500GB or 1TB disk capacities – a direct rival for Humax in the UK, and a quantum leap of faith for a DAB radio manufacturer like Pure. The Linux-based system can stream video and audio content via a network storage or uPnP-capable device. Pure says that it will eventually be possible to save standard-definition recordings onto a USB stick for viewing on another device such as a laptop.

These features and services will be enabled via free software updates, and Pure told me that more add-ons like Catch-Up TV are being worked on. Like the Humax HDR-Fox T2, the Avalon can also play compatible media content via the USB slots, but the Pure Avalon 300R can also use its built-in Wi-Fi for its Internet connection without needing a separate USB dongle. It's still early days for Pure, but the race is on to see which brand delivers Catch-Up TV first.

Will Pure's Avalon 300R Connect Freeview+ recorder prove a challenge to Humax? Rear view showing Four HDMI ports and Ethernet connection; Wi-fi is built in.

Wireless world

Also, in the April issue, I sugegsted how to upgrade the network speeds and reliability of a typical wireless PC using a PCI-e wireless adaptor. A twin antenna MIMO card costs typically £10 ($15) and can be a worthwhile upgrade. It takes just a couple of minutes and is very easy to do yourself, but obviously check the type and availability of expansion slots on the motherboard first.

In days of yore, before ADSL existed, let alone Wi-Fi or tablet computers, I was forced to use 56K dial-up networking for Internet access on a Windows XP laptop. If I wanted 'wireless' Internet connectivity on my laptop, well, BT offered a cordless DECT contraption consisting of a bulky transmitter that plugged into a phone socket, and a USB receiver as big as a packet of cigarettes that plugged into a USB port and rested itself on the sofa. It worked well enough until a Windows XP service pack update knocked it out and the drivers were never updated.

Far more user-friendly options for wireless networking are available today, and having streamlined my home network as far as possible, my attention turned to my main laptop. Like many laptops more than a few years old, mine has a built-in 54g (54 megabits per second) wireless adaptor whose antenna is a single wire looped around the screen. Older laptops may contain 802.11b (11Mbps) adaptors, which can be painfully slow on today's worldwide web.

However, if you use an 802.11n wireless router, then for a few pounds you could try an 802.11n USB adaptor on your laptop, to give its wireless connectivity a new lease of life. Simply switch off the internal wireless adaptor and plug in a higher-speed USB device instead and install the device driver from a CD or download.

Adaptability

USB Wi-Fi adaptors can cost as little as £5 on eBay, with some offering speeds of up to 300Mbps. Check compatibility carefully to ensure suitable Windows, Mac or Linux drivers are available for your machine. The main drawback is that as the USB dongle sticks out somewhat, care is needed to avoid damaging the laptop accidentally.

I tried a **TP Link TL-WN823N Mini 300Mbps** adaptor with MIMO technology, which installed perfectly and my laptop was soon enjoying sprightlier connectivity. As a bonus, in Windows 7 the TP Link WN823N USB dongle has a 'Soft AP' mode, allowing it to behave like a wireless AP (access point) instead, when hooked to the USB port of a wired Ethernet device.

This could extend home Wi-Fi coverage, for example allowing a (wired Ethernet) laptop to 'transmit' Wi-Fi to a smartphone or tablet nearby. It might save you the cost of a wireless router or range extender as a stop-gap measure. Some unbranded USB adaptors sold on eBay for £6 offer wireless AP mode too.

In use, the TP Link dongle stands approximately 20mm proud of the USB port and also has a password-free secure QSS (quick security setup) button that some might try to experiment with. My experiences with similar WPS (Wi-Fi Protected Setup) setups have never been good, but the snappy improvement over the laptop's built-in wireless adaptor made it a worthwhile investment.

Readers can email me at **alan@epemag.demon.co.uk** or write to the editor at **editorial@wimborne.co.uk** for possible submission in *Readout.*

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say?

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☆ LETTER OF THE MONTH ☆

Circuit Wizard text

Dear editor

Being a regular user of Circuit Wizard I was interested to read Lloyd Stickell's comments about this very versatile software package (*Readout*, *EPE*, Feb 2013). In particular, I would like to respond to Lloyd's criticism of Circuit Wizard, which read:

'There seems to be no way of adding random text to a circuit drawing; eg, labelling switch terminals or annotating any point of interest.'

I own the professional version of Circuit Wizard, and it is certainly possible to insert random text into a circuit diagram in a quick and simple way. I cannot comment on whether this is possible with the standard version of Circuit Wizard.

I hope the following will be of assistance to Lloyd – it's how I add text to a circuit diagram when using my version of Circuit Wizard:

- Click on 'Project'
- Move the cursor down to 'Circuit Symbols'
- On the menu that appears, click on 'Label'
- Move the cross-hairs that appear to the location where you want the text to be located
- Click the mouse
- In the dialogue box that appears, type in the required text
- Click 'OK'.

If no more text is to be inserted into the circuit diagram for the time being, right-click the mouse or click on the arrow symbol to remove the cross-hairs and return to the usual pointer cursor.

You can move the text around in the same way you would move circuit symbols. To edit text, just double-click on it. Plus, you can right-click on the inserted text and select 'Font' to resize it.

Alternatively, to insert text, simply press F4, but this only appears to work after the longer method described above has been used at least once after entering the software.

Lloyd, I hope this helps.

Chris Hinchcliffe, Dorset, by email

Matt Pulzer replies:

Most helpful Chris, many thanks.

Programming PICs for projects

Dear editor

My son and I were thrilled with the *Christmas Lighting Controller* and want to build one. We'd like to know how we can buy the programmer with the code, or how to program the controller. Is there a manual explaining how to do it? What hardware would we need to program it?

We live in the Netherlands and subscribe to your digital magazine – we really like it!

Charles Lekx, by email

Alan Winstanley replies:

This is an advanced project using mains electricity on multiple sockets and we recommend it for advanced constructors only. *Do not attempt it unless you have a good working knowledge and experience of building mains-powered projects. The slave unit has areas of the PC board where components and tracks are at mains potential.*

Unfortunately, we can't provide individual technical support for the basics of microcontroller programming. We would anticipate that readers undertaking a project like this would already have the necessary skills and experience. We recommend you visit **www.chatzones.co.uk** *where online help from other users is readily available.*

Matt Pulzer replies:

I would just like to add a few points to Alan's reply.

1) You can purchase a pre-programmed dsPIC from Silicon Chip*:* **parts@siliconchip.com.au**

2) If you want to start learning how to program PICs then there is no better route than Mike Hibbett's EPE *series* PIC 'n Mix, *which has been running in the magazine for many years now.*

3) You can buy a powerful, but not expensive PIC programmer from MicroChip (the PICkit 2 or PICkit 3), via **www.microchip.com***, see:* **http://tinyurl.com/43vs3rz.** *Mike has written extensively about how to use this clever little programmer.*

4) EPE *sells CD-ROMs with useful educational and project-oriented material devoted to using and enjoying PICs.*

5) If you are beginners when it comes to using PICs, then I strongly recommend you buy the pre-programmed PIC from Australia, and then learn to use the PICkit separately. It is a complex project that uses quite an advanced PIC.

7) Last, to echo Alan, SAFETY FIRST – please only tackle this project if you are genuinely experienced in building projects that use mains electricity – we don't want to lose any readers!

Great to hear from readers in the Netherlands – Dank u!

Digital Spirit Level display problem

Dear editor

I'm making the *Digital Spirit Level* project (March 2013). Has anyone complained that the FND500 displays that are 15mm wide don't fit the published PCB?

Pete Russell, via email

Leo Simpson, publisher, Silicon Chip magazine *replies:*

You are the first to have brought our attention to this problem. It turns out that the FND500 displays that are sold by Jaycar and Altronics – and used in our prototypes – are not the genuine article. They are pin-for-pin compatible with the original FND500 spec, which is a very old device originally sourced by Fairchild (we think), but their body is narrower. So the 'proper' FND500s don't fit, as you have found.

These devices appear to be identical to Liteon LTS547AP, although we cannot be completely sure.

The odd thing is that these narrower displays have been sold as FND500s by Jaycar et al *for quite few years, and no one has questioned this situation.*

The simple fix is to buy the displays from Jaycar or Altronics, but I realise that might rankle a bit since you cannot use the FND500s you have on hand in this project

Matt Pulzer replies

I've done some 'googling' and can echo Leo's points. It does appear that there are two widths of FND500, which is both annoying and highly unusual.

For the Jaycar ones, the pins go nearly to the sides, allowing parallel placement on the project PCB. However, for other types there is a fair bit of extra encapsulation on either side, which will prevent side-by-side positioning of the displays on the PCBs.

I am sorry you will need to go to some expense to rectify this. We do check parts very careful, and I think this is the first time I have come across such an anomaly.

Switching mains power

Dear editor
In the future, it is possible that we electricity consumers may have our 'peak loads' forming an extra part of the electricity bill. I understand the meter industry may well be designing meters for this requirement. (It is already in use in companies that have large peak loads.)

With this in mind, I have been searching recently for information on circuits to control a mains switch with a 3kW load, specifically using a micro (in my case, a suitable Arduino board). I could easily use a relay, but I want a compact solid-state unit. I do not need to 'control' the mains – just be able to switch on and off. I want to avoid producing spikes (interference), and the load will only be 'resistive'.

I am keen to increase my own knowledge in this area. I do not know enough about FETs, MOSFETs, solid-state switches, triacs and SCRs to make a sensible design decision or appreciate the cost implications. Most important of all, there could also be safety implications, particularly heat dissipation.

Despite a good hunt, there seems to be a lack of useful data on the Internet or in technical books. All I can find is information up to 24V DC. I am sure that I'm not the only one who is interested in this problem.

I'm now retired, but started building my first battery projects at the age of four. I spent 50+ years in hardware/software, both as a hobbyist, and as a commercial and military contract engineer. I started reading electronics in the early 1960s and enjoy reading *EPE.*

'Gateman', via Chat Zone

Alan Winstanley replies:

Thank you for the very interesting letter and it's great to hear from readers who have such a long-established interest in electronics.

We try to cover many new developments while not spreading ourselves too thinly, and we're presently focussing on the Raspberry Pi. Your mains switching application sounds ideal for a triac, especially if simple resistive loads are being driven.

*Mail order specialists such as ESR Components (**www.esr.co.uk**) sell a good range of triacs and the BTA16-600B is a 600V 16A device with isolated tab that may be suitable. An optically-triggered triac provides a safe light barrier between the driver and the load, and the MOC3041 (also listed by ESR) is a popular triac opto-coupler with built-in zero-crossing to eliminate interference in this type of circuit.*

Matt Pulzer replies

While I do appreciate you have a preference for solid-state switching, I would urge you to consider a relay – it may be 'Victorian' technology, but it is a good, simple solution that can easily interface with 21st century technology such as an Arduino board. Perhaps you might like to look at three of our projects from a couple of years ago: USB-Sensing Mains Power Switch *(Jan 2011);* Tempmaster Mk.2 *(Feb 2011) and* PIR-Triggered Mains Switch *(April 2011). All these switch mains power with a relay in a compact unit.*

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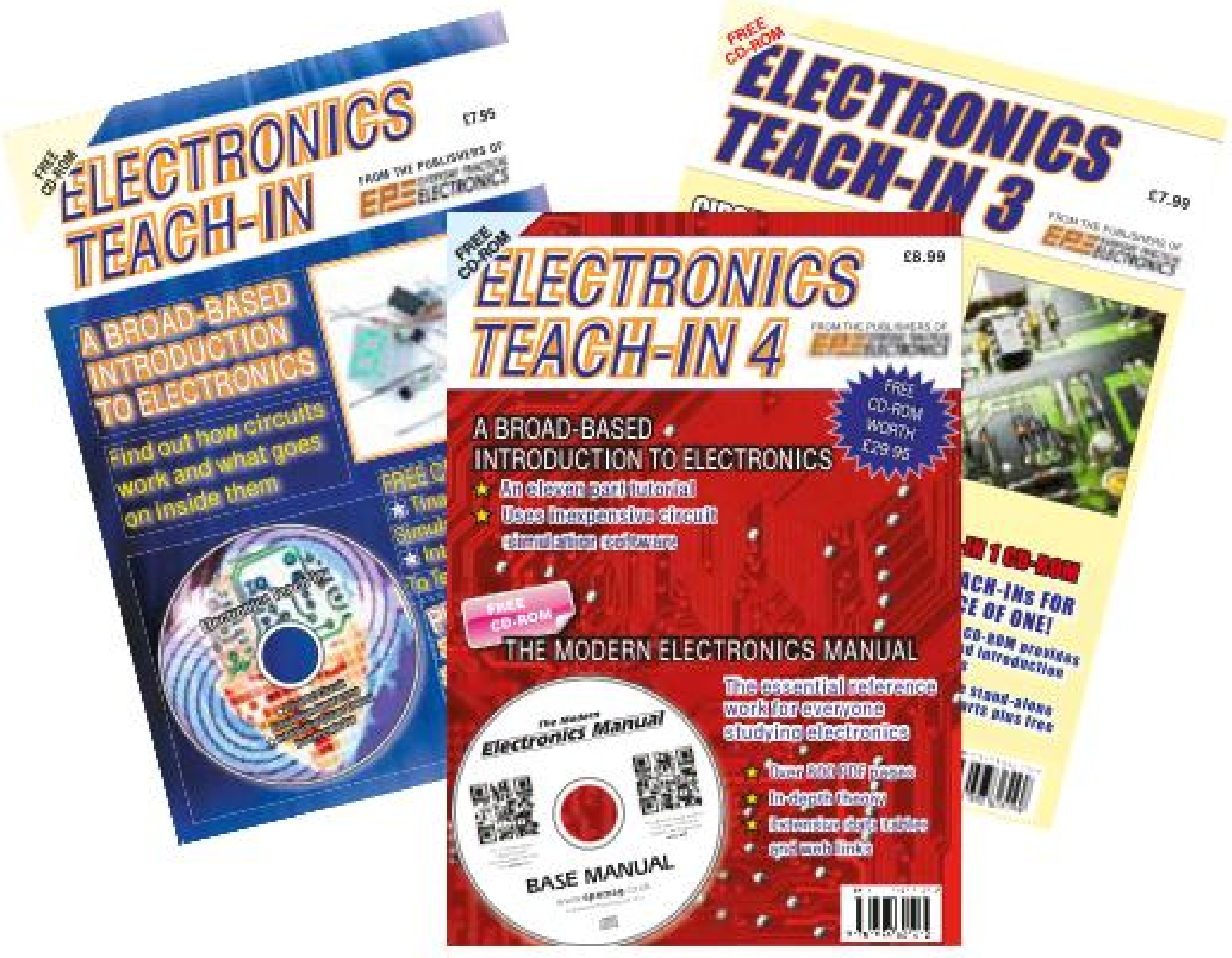

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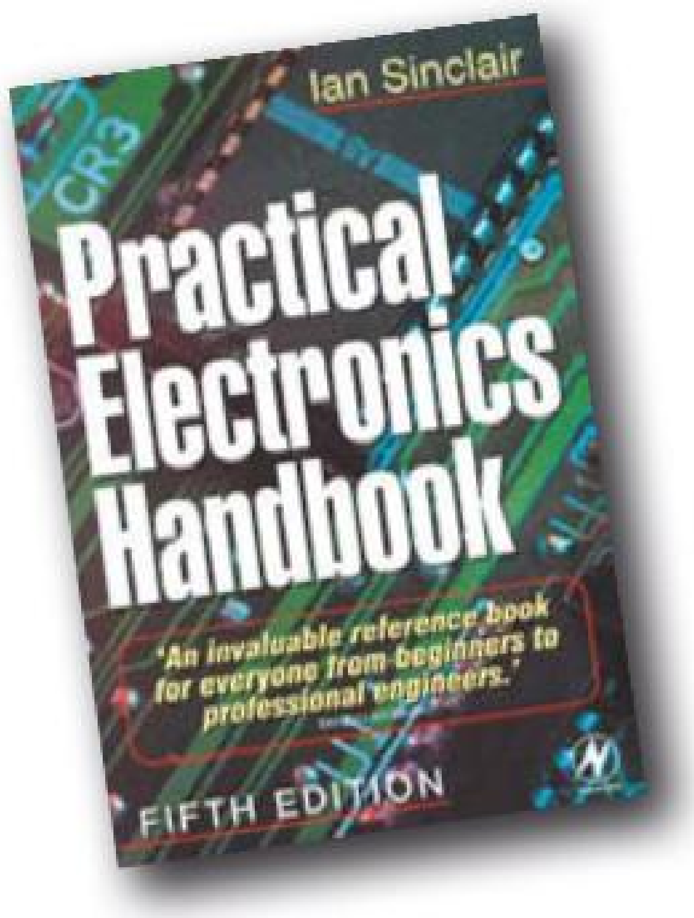

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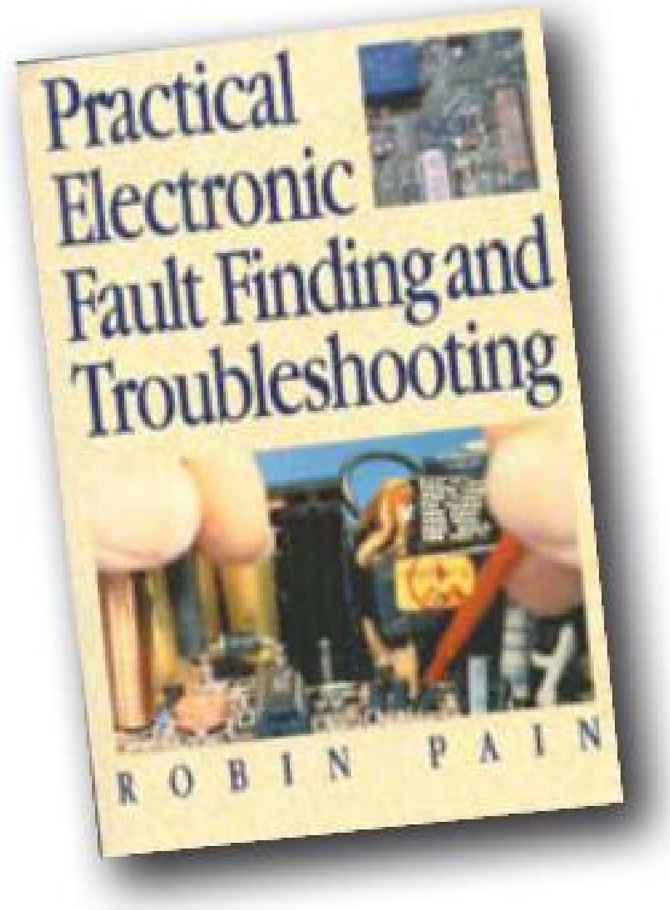

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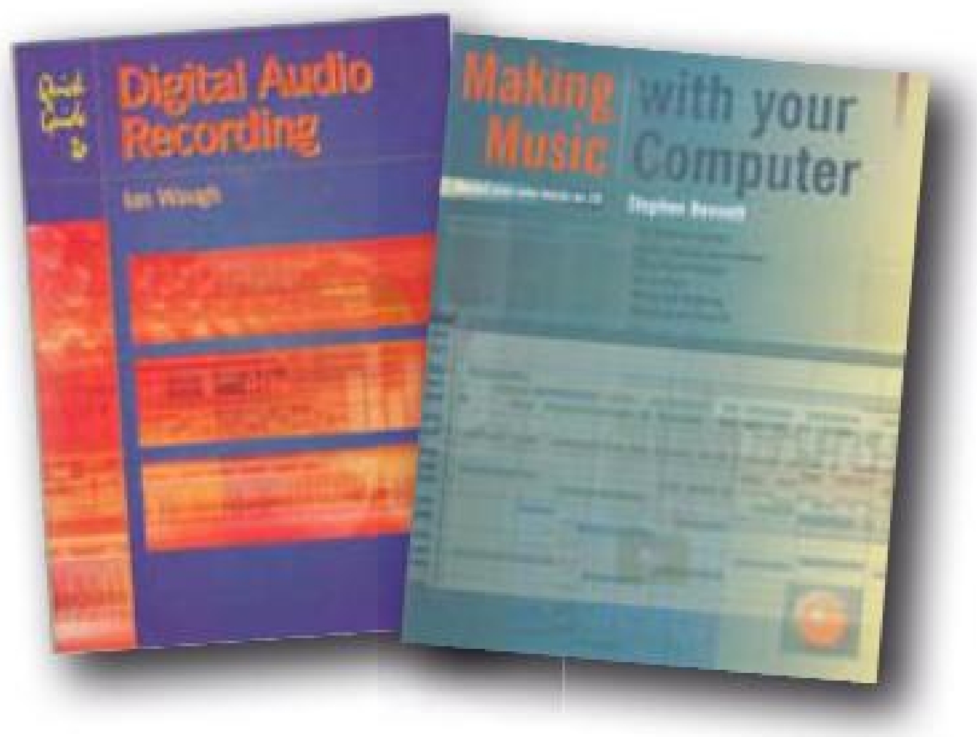

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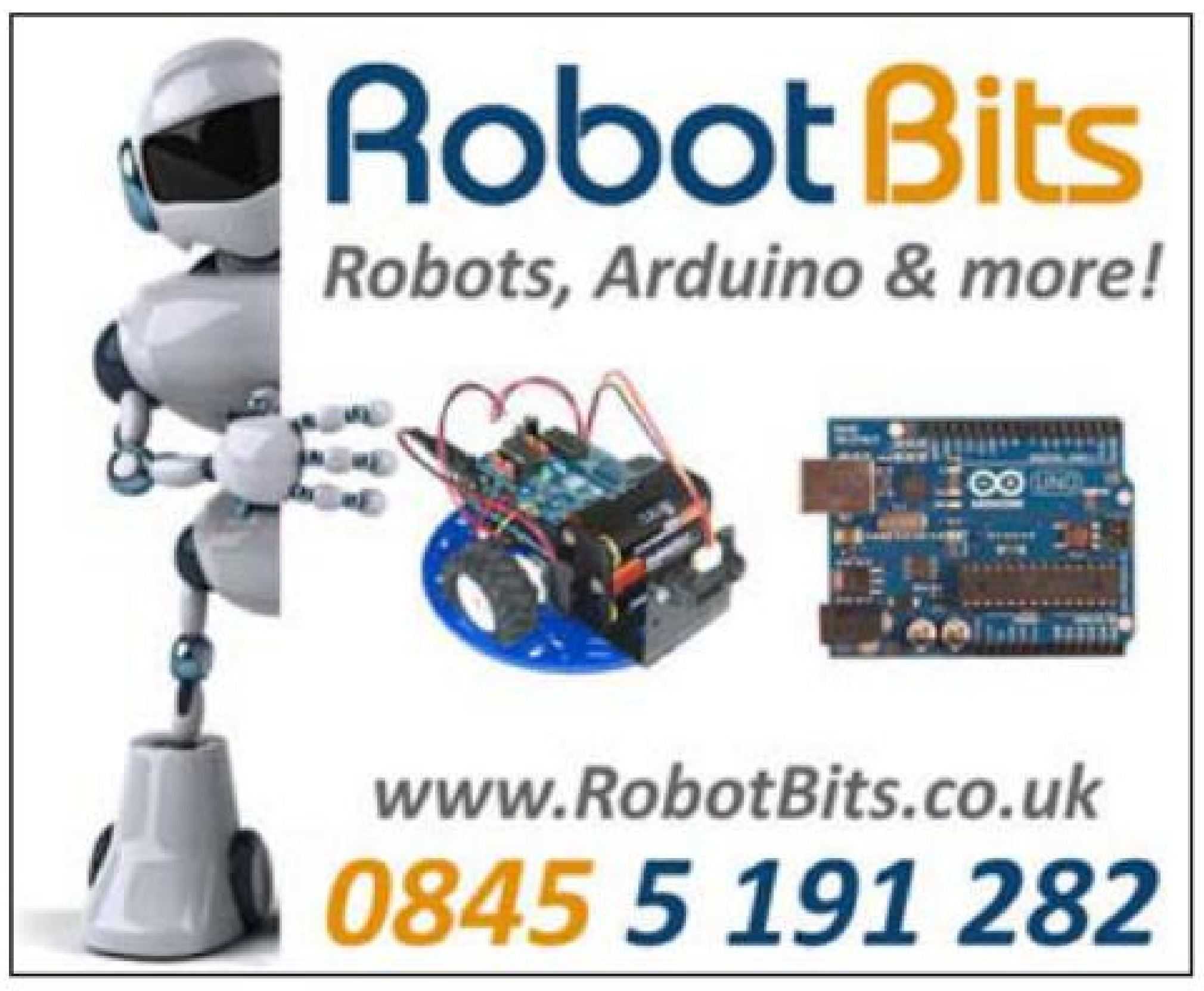

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Next Month

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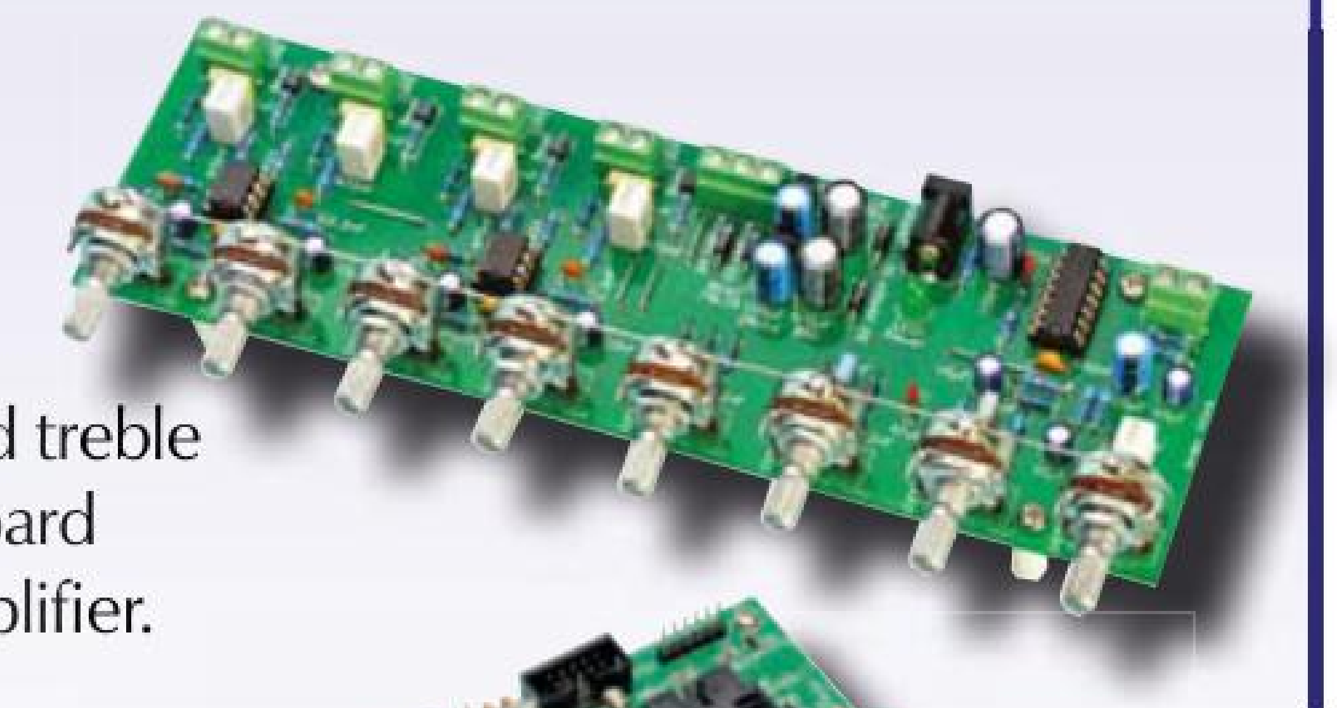

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In the current issue we described our new programming adaptor board, which works in conjunction with an in-circuit serial programmer (ICSP) to program most 8-bit and 16-bit PIC and 8-bit Atmel AVR microcontrollers. Next month, we give the details of how to build it and use it.

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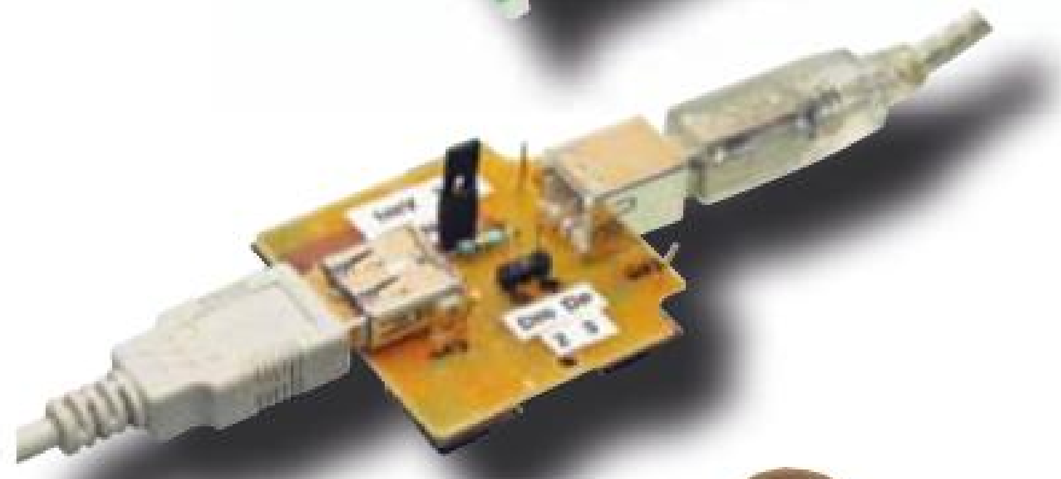

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Jump Start – Simple Radio

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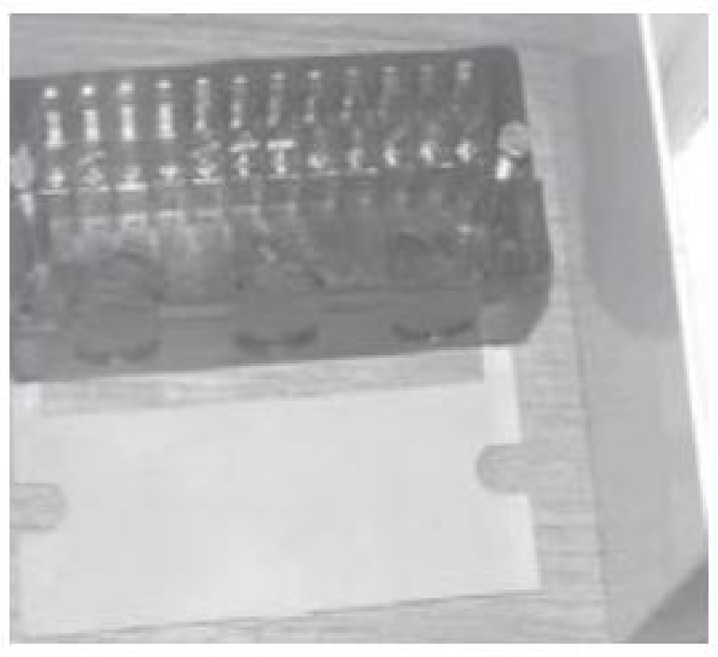

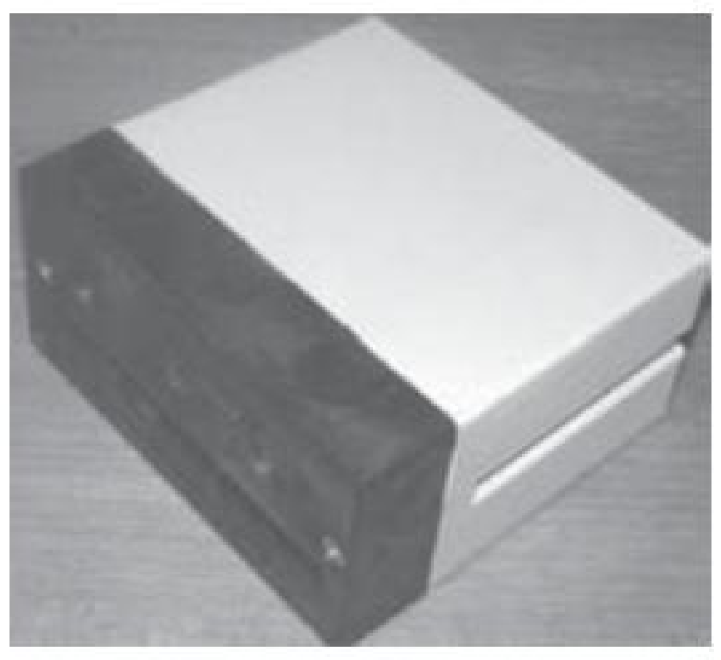

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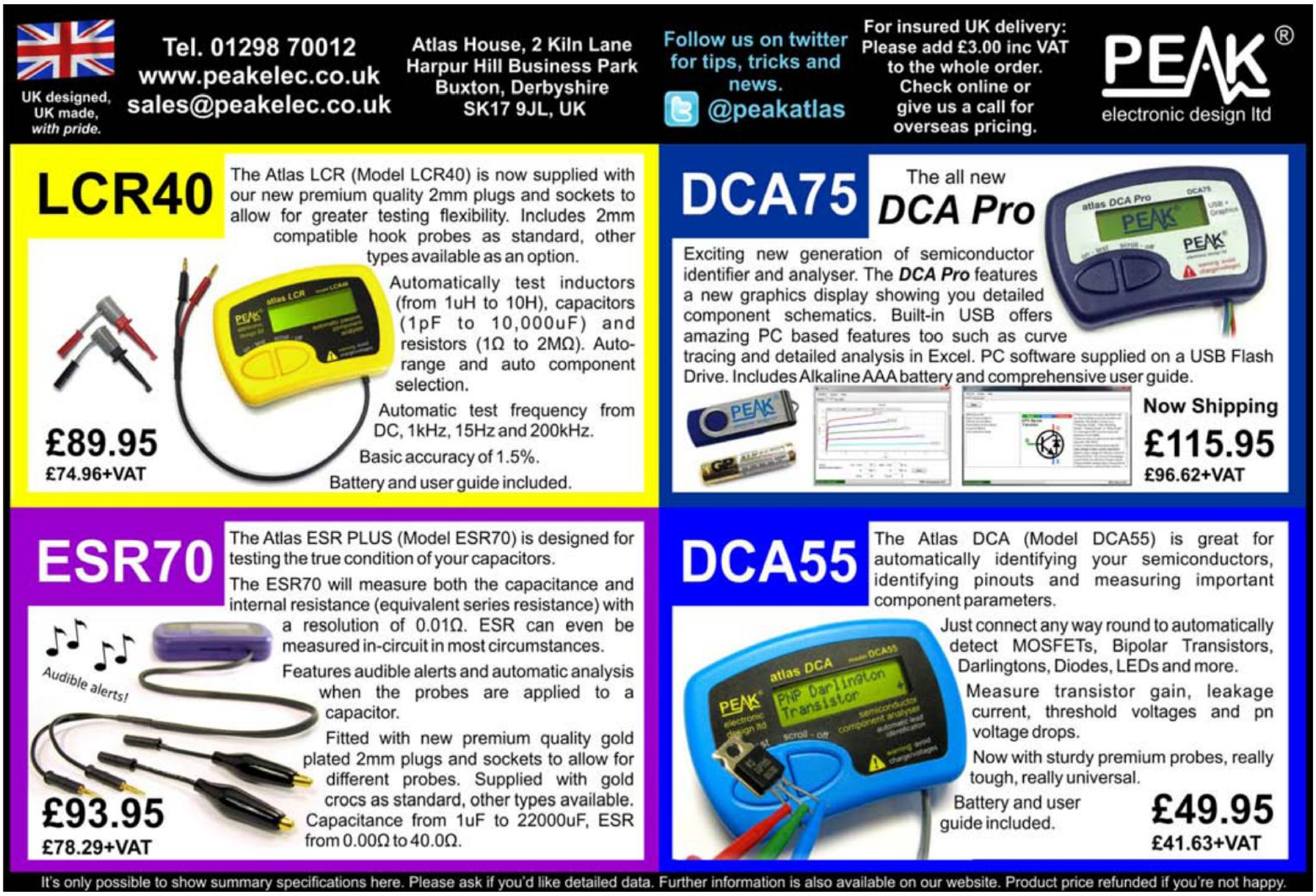

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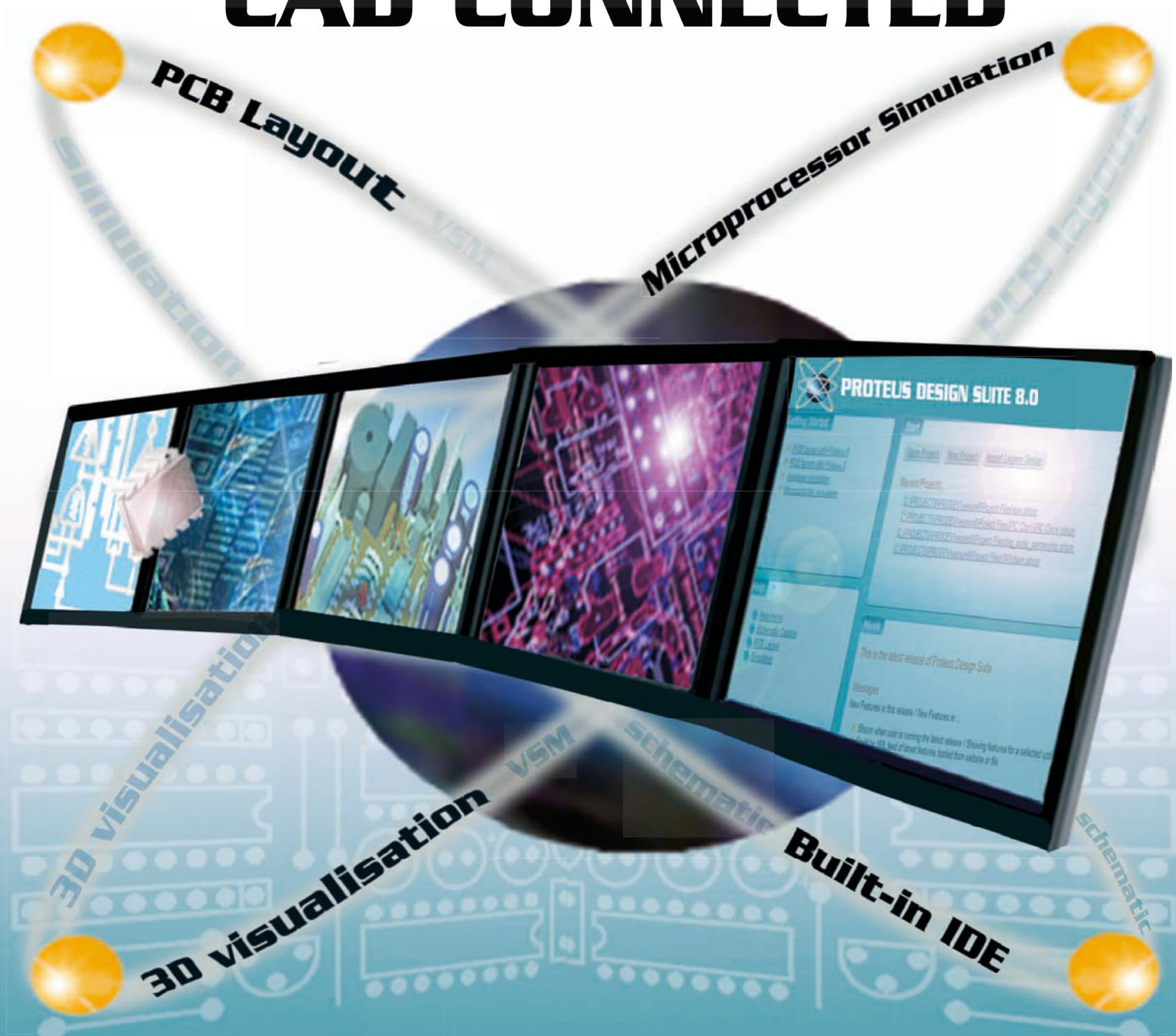
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